Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

PRE-DESIGN STUDIES WORK PLAN

FINAL

Prepared for

Lower Duwamish Waterway Group

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Acronyms

95UCL	95% upper confidence limit for the mean
AC	activated carbon
AOC	Administrative Order on Consent
ARAR	applicable or relevant and appropriate requirement
Axys	Axys Analytical Services, Ltd.
AWQC	ambient water quality criteria
BAZ	biologically active zone
BCM	bed composition model
BEHP	bis[2-ethylhexyl phthalate
BHC	benzene hexachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
COC	contaminant of concern
COPC	contaminant of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPUE	catch per unit effort
CSM	conceptual site model
CSO	combined sewer overflow
CV	coefficient of variation
CWA	Clean Water Act
DDT	dichlorodiphenyltrichloroethane
DL	detection limit
DQO	data quality objective
DRCC	Duwamish River Cleanup Coalition
EAA	early action area
Ecology	Washington State Department of Ecology

EDL	estimated detection limit
EIM	Environmental Information Management
EPA	US Environmental Protection Agency
ENR	enhanced natural recovery
GIS	geographic information system
Integral	Integral Consulting Inc.
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LOE	line of evidence
MDD	minimum detectable difference
MHHW	mean higher high water
MIT	Massachusetts Institute of Technology
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
NOAA	National Oceanic and Atmospheric Administration
ODEQ	Oregon Department of Environmental Quality
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
PE	polyethylene
PRC	performance reference compound
PVC	polyvinyl chloride
QC	quality control
QAPP	quality assurance project plan
RAL	remedial action level
RAO	remedial action objective
RARE	Regional Applied Research Effort
RI/FS	remedial investigation / feasibility study

RL	reporting limit
RM	river mile
RME	relative margin of error
ROD	Record of Decision
SCO	sediment cleanup objective
SIM	selective ion monitoring
SMS	Washington State Sediment Management Standards
SQS	sediment quality standards
STM	sediment transport model
SVOC	semivolatile organic compound
SWAC	spatially weighted average concentration
TAG	Technical Advisory Group
TBT	tributyltin
TEF	toxic equivalency factor
TEQ	toxic equivalent
TOC	total organic carbon
TTL	target tissue level
USACE	US Army Corps of Engineers
USGS	US Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
Windward	Windward Environmental LLC
WQC	water quality criteria

1 Introduction

In 2000, the City of Seattle, King County, the Port of Seattle, and The Boeing Company, working collectively as the Lower Duwamish Waterway Group (LDWG), agreed in an Administrative Order on Consent (AOC) to conduct a remedial investigation / feasibility study (RI / FS) for the Lower Duwamish Waterway (LDW) with oversight by the US Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology). In September 2001, the LDW was formally listed as a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) site; in February 2002, the LDW was formally added to the National Priorities List as a Washington Model Toxics Control Act (MTCA) site. The RI was completed in 2010 (Windward 2010a) and the FS was completed in 2012 (AECOM 2012). A record of decision (ROD) was issued by EPA in 2014 (EPA 2014).

A third amendment to the AOC (EPA 2016) specified pre-design studies to “help EPA ensure that all remedial design data needs are addressed in the appropriate sequence and without delay” to advance the implementation of the ROD. This document is the work plan for the pre-design studies specified in the third amendment. Eleven tasks that are outlined in the third amendment are described herein. These tasks, including this work plan (Task 1), are:

- Task 1: Pre-design studies work plan
- Task 2: Existing data compilation
- Task 3: QAPPs and associated support documents
- Task 4: Sampling and analysis
- Task 5: Data reports
- Task 6: Data evaluation report
- Task 7: Waterway user survey and assessment of in-water structures work plan
- Task 8: Waterway user survey and assessment of in-water structures report
- Task 9: Recovery category recommendations
- Task 10: Design strategy recommendations report
- Task 11: Support for development of seafood consumption institutional controls

Task 11, support for development of seafood consumption institutional controls, is being addressed through an EPA-led process outside of the scope of this work plan. Thus, this task is not discussed further herein.

1.1 Study Context and Conceptual Site Model

The purpose of the pre-design studies, the context of proposed baseline sampling relative to other monitoring that will be conducted as part of the remedy, and the conceptual site model (CSM) are discussed in this section.

1.1.1 Purpose of pre-design studies

The 10 tasks that are described in this work plan are intended to fulfill the following objectives, as outlined in the third amendment (EPA 2016):

- Consistent with Section 13.2.3 of the ROD (EPA 2014), establish post-early action area (EAA) cleanup baseline conditions in environmental media, evaluate the effectiveness of EAA cleanups and the degree to which natural recovery has occurred since the RI/FS, establish baseline data for comparison to post-remedial action data, and aid in the evaluation of source control.
- Perform a survey of waterway users and an assessment of in-water structures to inform recovery category recommendations and technology assignments.
- Identify other site-wide and area-specific remedial design and remedial action information needs.
- Develop a strategy for remedial design phasing.

The scope of this work does not include the filling of area-specific design data needs, nor does it include duplication of characterization being conducted under MTCA at specific sites along the waterway.

1.1.2 Context within overall program

The pre-design studies described in this work plan are being conducted as a part of an ongoing process to address the site. This process has included an RI/FS (Windward 2010a; AECOM 2012) to study the site, to assess sources and risks to human health and the environment, and to evaluate cleanup alternatives. EPA's ROD outlined the sediment cleanup plan for the LDW. The next phases of the cleanup process include pre-design studies, remedial design, construction of the remedy, and monitoring of the remedy outcome. Source control actions in support of the cleanup have been underway and are ongoing. The pre-design studies described in this work plan constitute a subset of the data collection efforts that have been or will be conducted within the LDW.

Numerous data have been collected within the waterway to date. As part of the RI/FS-associated data compilation and collection (Windward 2010a; AECOM 2012), 3,359 sediment samples, 473 tissue samples, and 1,034 water samples (including porewater, surface water, and seep samples) were analyzed or compiled, encompassing the period from 1990 to 2010. In addition, 232 storm drain and combined sewer system source tracing solids were analyzed, encompassing the period from 2002 to 2007.

Since the RI/FS data were compiled and collected, additional data have been collected by various parties. As part of the Task 2 activities described in Section 3.1, LDWG has compiled[1] additional data for 1,434 sediment samples, 2 tissue samples, 162 water samples, 320 groundwater samples, 664 storm drain and combined sewer system source tracing solids samples, and 54 bank samples, encompassing the period from 2010 to 2016.

Following the pre-design studies described in this work plan, a considerable amount of detailed area-specific data will be collected during design, as part of construction, during post-construction, and during long-term monitoring. An overview of these sampling efforts is presented in Table 1-1.

Site-wide characterization to determine baseline conditions for remedial action objectives (RAOs) 1, 2, and 4[2] will be conducted under pre-design sampling. While the frequency and timing of long-term monitoring are not being determined as part of the pre-design studies, it is assumed that the baseline sampling approach outlined in this work plan[3] will be repeated in the future at appropriate intervals. Baseline data combined with long-term monitoring will allow trend analysis to assess progress toward compliance with cleanup goals. Area-specific monitored natural recovery (MNR) monitoring for RAO 3 compliance will be conducted as post-construction monitoring over a 10-year period to determine whether RAO 3 goals are achieved. Additional data collection efforts will be conducted in support of design and construction, as discussed further in Section 3.9. Appendix K of the FS (AECOM 2012) provides a conceptual overview of monitoring associated with remedy implementation and effectiveness over the long-term.

[1] These data were compiled as part of two data compilation memoranda submitted to EPA(Windward and Integral 2017b; Windward 2017c).

[2] RAO 1 pertains to risks from seafood ingestion (human health), RAO 2 is related to direct contact risks (human health), RAO 3 is related to risks to the benthic invertebrate community (ecological health), and RAO 4 pertains to risks to higher-trophic-level species (fish, crabs, birds, and mammals - ecological health).

[3] Future data may inform modifications to the approach; any changes would be coordinated with EPA.

Table 1-1. Overview of environmental sampling efforts by project phase

Sampling Type	Sampling by Project Phase				
	Pre-Design Studies Sampling[a]	Design Sampling[a]	Construction Monitoring[a,b]	Post-Construction Monitoring[a,b]	Long-Term Monitoring[a,b]
Baseline/ river-wide sampling	· 0–10 cm surface sediment (site wide for RAOs 1, 2, 4[c]) · 0–45 cm sediment (clamming and beach play area wide for RAO 2[c]) · Fish, crab, clam tissue (for RAO 1[c] and fish advisory) · Surface water (for water quality ARAR) · Porewater (for RAO 1[c])	na	na	na	· 0–10 cm surface sediment (site wide for RAOs 1, 2, 4[c]) · 0–45 cm sediment (clamming and beach play area wide for RAO 2[c]) · Fish, crab, clam tissue (for RAO 1[c] and fish advisory) · Surface water (for water quality ARAR)
Source control/other characterization sampling	· Bank sampling – soil source control · Near outfall sampling – outfall source control · Seeps – groundwater source control	source control sufficiency sampling as needed by various parties	na	possible recontamination monitoring at certain locations	none identified at this time.
Location-specific/ technology-specific sampling	none identified as time critical for predesign purposes (Section 3.9).	surface and subsurface sediment samples for: · Final technology assignments · Final boundaries of dredging, capping, ENR, MNR > SCO · Cap modeling and design, as needed	· Water quality monitoring · Confirmatory/ residual sediment sampling in dredge areas without backfill or in perimeter areas · Cap/ENR placement verification	· MNR > benthic SCO (RAO 3[c]) surface sediment monitoring over 10-year period (contingent actions if RAO 3[c] goals not achieved in reasonable timeframe) · ENR surface sediment monitoring over a defined period (contingent actions if > RALs (RAO 3[c] not met or maintained)	cap monitoring

[a] See Appendix D for a detailed summary of additional data/information to be gathered during this phase.

[b] Section 7.3.1 of the LDW FS (AECOM 2012) provides additional background regarding the general purpose and objectives for this monitoring activity.

[c] RAOs are defined as follows: 1 – seafood consumption (human health); 2 – direct contact (human health); 3 – benthic invertebrates (ecological); 4 – fish, crab, wildlife (ecological).

ARAR – applicable or relevant and appropriate requirement
ENR – enhanced natural recovery
FS – feasibility study
LDW – Lower Duwamish Waterway
na – not applicable
MNR – monitored natural recovery
RAL – remedial action level
RAO – remedial action objective
SCO – sediment cleanup objective

1.2 ROLES AND RESPONSIBILITIES

Many parties are participating in the pre-design studies being performed by LDWG and its contractors; EPA and its contractor the US Army Corps of Engineers (USACE) are providing oversight.

Windward Environmental LLC (Windward) is coordinating activities for LDWG (including managing the team of subcontractors) and leading the following tasks: work plan development (Task 1); data compilation and data management (Task 2); and baseline data study design, collection, reporting, and evaluation (Tasks 3 through 6). Terrastat Consulting Group is providing statistical analysis and study design support for these tasks. Sediment Solutions, Clearway Environmental, Greylock Consulting, Fain Environmental, and Ramboll Environ all play supporting roles.

Integral Consulting Inc. (Integral) is working with Moffett & Nichol and Convergent Pacific LLC to design and implement the waterway users survey and structures assessment (Tasks 7 and 8). Integral is also leading the development of recovery category recommendations (Task 9) and preparing the design strategy report (Task 10).

Ecology and LDW stakeholders (e.g., Tribes, Duwamish River Cleanup Coalition [DRCC] Technical Advisory Group (TAG), and the National Oceanic and Atmospheric Administration [NOAA]) are participating in the review of pre-design study deliverables and providing input in accordance with the review process established by EPA. In general, this process involves LDWG submitting draft deliverables to EPA, which shares these documents with stakeholders, soliciting comments. Stakeholder comments are submitted to EPA and shared with LDWG; EPA considers stakeholder comments for incorporation into EPA comments. LDWG then addresses EPA comments.

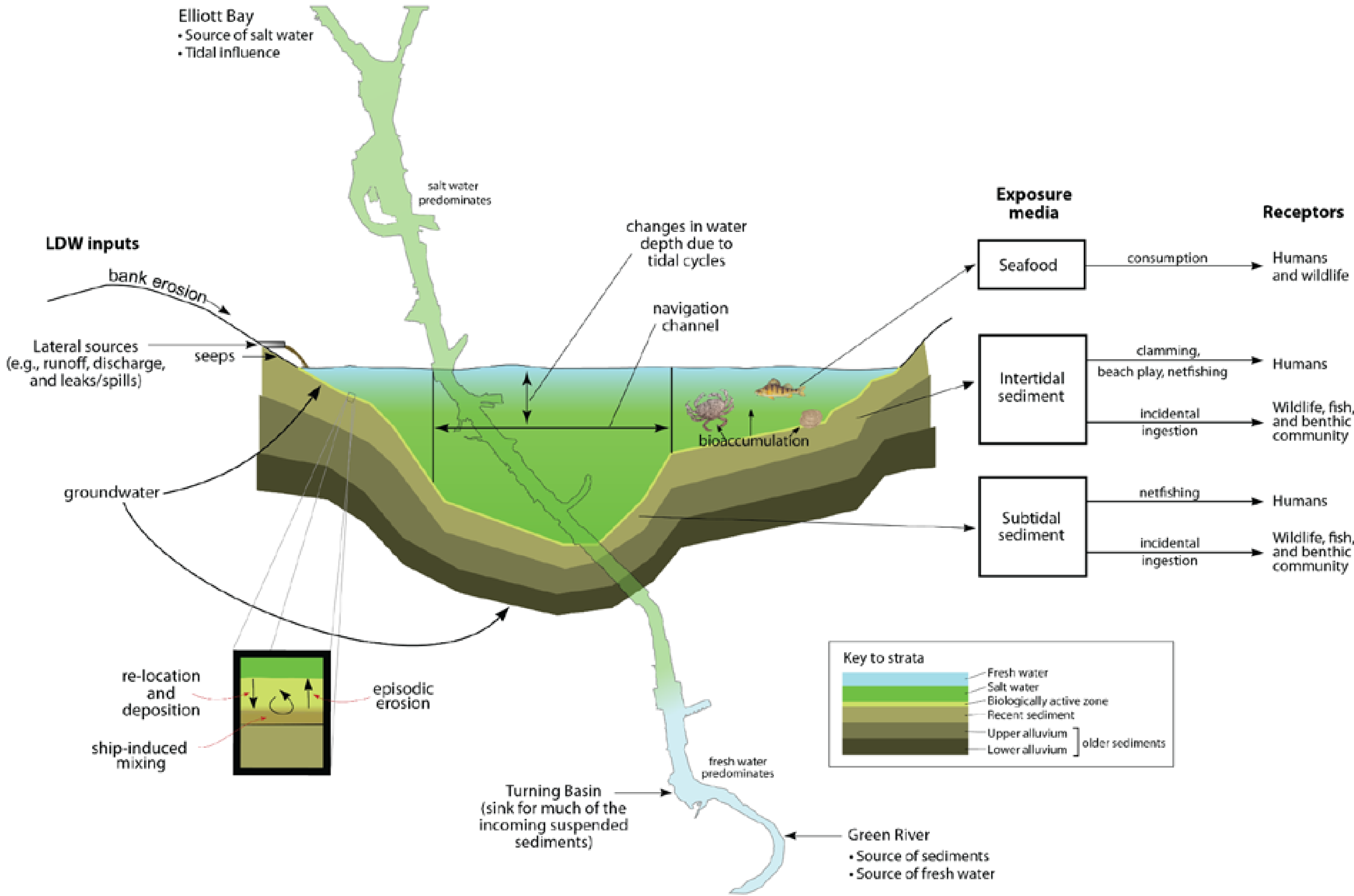
1.3 WORK PLAN ORGANIZATION

This work plan is divided into three sections. This section, Section 1, provides an introduction to the document. Section 2 provides a description of the CSM. Section 3 provides a summary of each task, including its purpose and approach. Section 4 presents a table summarizing the schedule and specified deliverables for each task.

Six appendices support this work plan. Appendix A contains the statistical support for the study designs, Appendix B presents selected analytical methods and reporting limits (RL), and Appendix C presents the data management plan. Appendix D provides a table that contains context for the pre-design studies, listing LDW data needs and timing considerations and specifying the effort whereby these data will be collected (e.g., enhanced natural recovery/activated carbon [ENR/AC] pilot study, pre-design studies, remediation design investigations and engineering, and remedial action). This summary-level information will be further developed in the Task 10 design strategy recommendations report to assist in the planning and sequencing of design data acquisition. Appendix E contains the porewater addendum. Appendix F contains the results of the cPAH analysis of clam siphon skin.

2 Conceptual site model

The CSM for the LDW describes how the system functions, provides an overview of the major processes affecting the distribution and movement of contaminants at the site, and describes the exposure pathways (primarily consumption of contaminated seafood and direct contact with sediment) by which people and animals can be exposed to these contaminants (Figure 2-1). This information is helpful in developing study designs to assess the baseline conditions that will form the foundation for long-term monitoring of the LDW.



Note: Adapted from figure developed as part of the LDW RI (Windward 2010a).

Figure 2-1. Conceptual site model for exposure pathways and physical processes in the LDW

2.1 ENVIRONMENTAL SETTING

The in-water portion of the LDW, which extends from river mile (RM) 0 to RM 5.0, was modified in the early 1900s; the river was converted from a natural estuary to a straightened waterway that could better accommodate commercial traffic. Since that time, the central portion of the river (up to the turning basin at RM 4.7) has been dredged to maintain sufficient depths for navigation. Today, USACE generally performs maintenance dredging in the turning basin and in a nearby portion of the navigation channel every 1 to 3 years (EPA 2014). Dredging in other portions of the navigation channel occurs as needed to maintain the authorized navigation depth. The federal navigation channel exists down the center of the LDW; subtidal areas border the navigation channel, and shallow intertidal bench areas exist along the shoreline (AECOM 2012). The shoreline, or bank, of the waterway is comprised of approximately 88% steepened hard surfaces (e.g., riprap, sheet piling walls, and bulkheads), 0.7% concrete boat ramps, and approximately 11% more gently sloped beach and intertidal areas that remain throughout the waterway.

2.2 PHYSICAL PROCESSES

This section describes the physical characteristics of the LDW, both for surface water and sediment.

2.2.1 Surface water

As discussed in Section 2.7 of the LDW RI (Windward 2010a) and in Section 2.3 of the LDW FS (AECOM 2012), the LDW is an estuarine system with a well-stratified salt wedge that is influenced by freshwater flowing into the LDW from the Green River upstream and a tidal influx of saltwater from Elliott Bay. As is typical of tidally influenced estuaries, the LDW has a well-defined interface (i.e., limited mixing occurs) between the freshwater moving downstream and the tidally influenced saltwater wedge that sits at the bottom of the waterway (AECOM 2012; Windward 2010a). The upstream extent of this salt wedge is dependent on tidal and flow conditions. Based on the physical characteristics of the LDW and the processes governing the movement of water and sediment, the waterway has been divided into three reaches (AECOM 2012; Windward 2010a):

- **Reach 1: RM 0.0 to RM 2.2 –** The salt wedge is always present in the lower reach of the LDW, although the toe of the wedge (i.e., the upstream-most extent) can recede as low as RM 1.8 during high flows during spring ebb tides. The salt wedge provides a protective barrier for the sediment in this reach, meaning bottom velocities that can scour occur relatively infrequently. Sedimentation rates, which are discussed in Section 2.2.2, are variable, although both the navigation channel and intertidal portions of this reach are net depositional.
- **Reach 2: RM 2.2 to RM 4.0 –** The salt wedge is generally present in this middle reach, except during high flows, when the toe of the wedge is often downstream

of this reach during ebb tides. As discussed in Section 2.2.2, sedimentation rates are variable and although some scour can occur, this reach is net depositional on an annual timescale.

- **Reach 3: RM 4.0 to RM 5.0** – The characteristics of this portion of the LDW are generally similar to those of a freshwater river, although the toe of the salt wedge can extend into and upstream of this reach during low and average flows. While this reach is net depositional on an annual scale, erosional events can occur periodically due to the higher flows and absence of the salt wedge in this upper portion of the LDW.

To illustrate the movement of the salt wedge in the LDW, Figure 2-2 shows the location of the salt wedge during both a low and high tide under specific river conditions (i.e., high upstream-flow conditions and spring tide). In this figure, the salinity gradient is shown from most saline (purple) to least saline (white). The purple layer at the bottom of the LDW represents unmixed saline water (which is the densest), with an upward progression to less saline water in the blue layer (which is less dense) as mixing occurs between the two layers. The white surface layer represents freshwater inflow from the Green River.

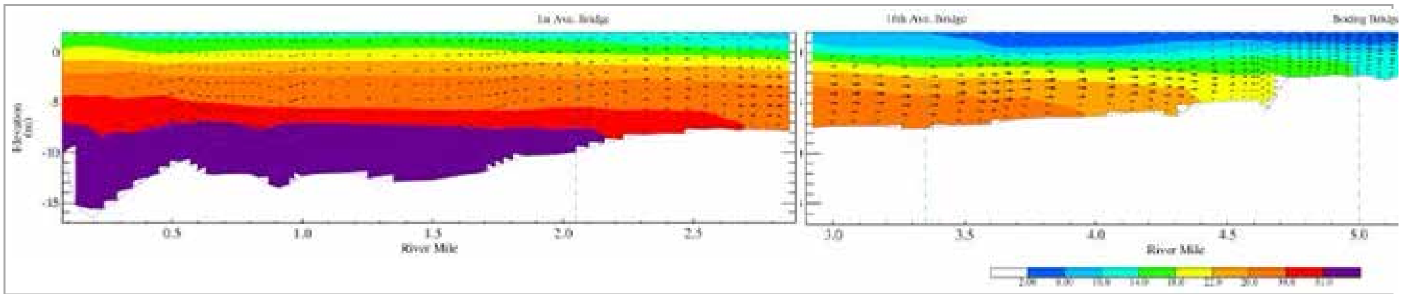


Figure A. Mean flow, high tide, and large extent of salt-water wedge

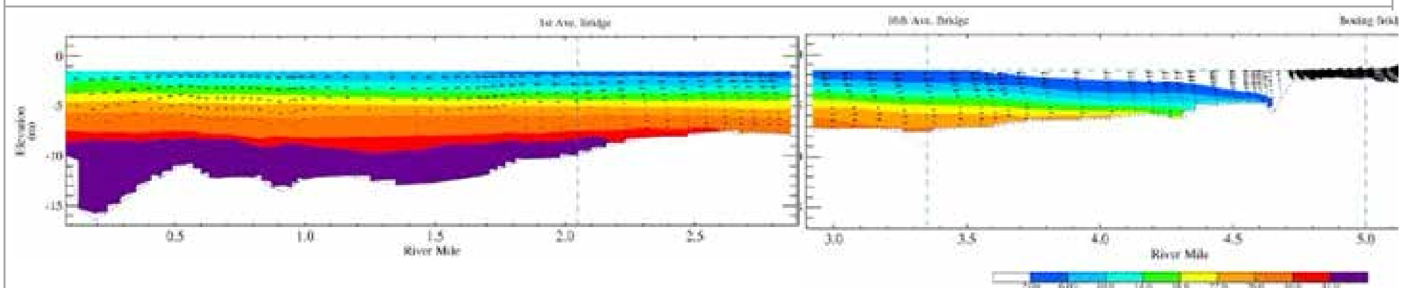


Figure B. Mean flow, low tide, and moderate/large extent of salt-water wedge

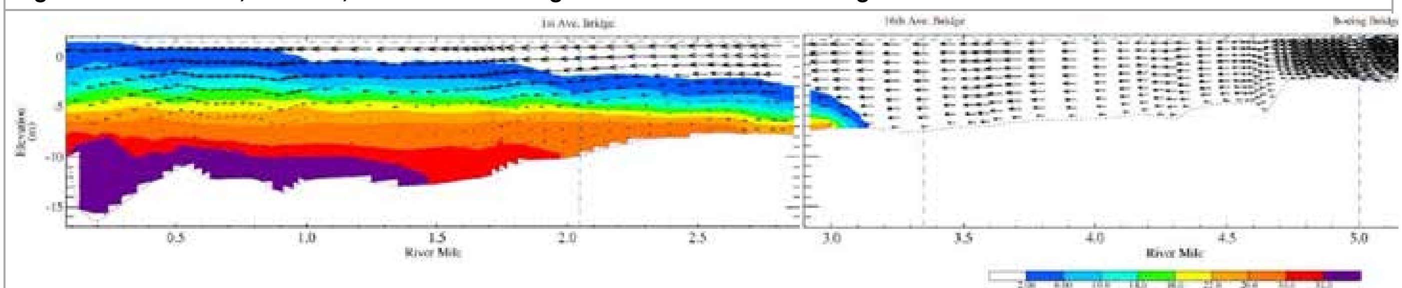


Figure C. 100 year high-flow event, high tide, and moderate/small extent of salt-water wedge

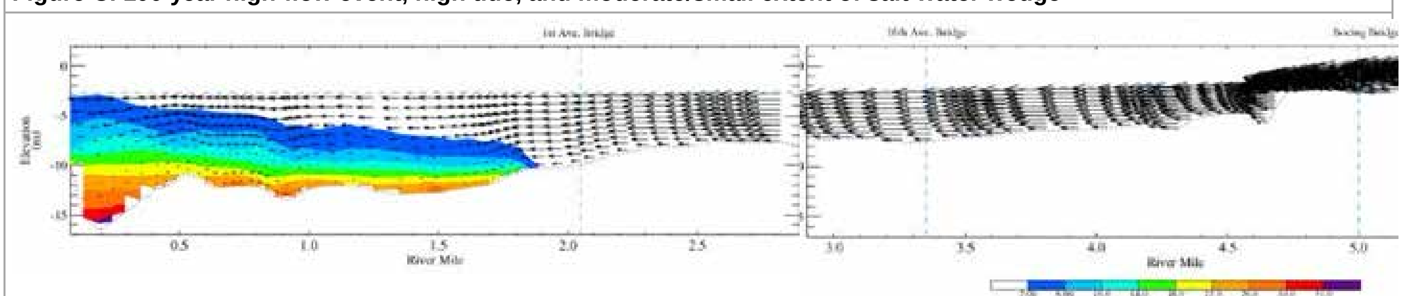


Figure D. 100 year high-flow event, low tide, and minimal extent of salt-water wedge

Figure 2-2. Salt wedge and salinity gradient in a model simulation of a spring tide in the LDW

Estuarine circulation results in a net upstream flow of saline water from the downstream end of the LDW; the further upstream the extent of the salt wedge, the longer its residence time[4] in the LDW. Depending on the extent of tidal forcing and the downstream flow rate, varying levels of turbulence along the saline / freshwater interface can occur, which results in mixing of these two layers and flushing of the brackish water out of the system (Geyer 2004; NOAA 2008). This dynamic affects contaminant concentrations in bottom water, as discussed in Section 2.3.

During each 24-hour period, the LDW experiences approximately two high tides and two low tides (two full tidal cycles are completed every 24 hours and 50 minutes), with tidal elevation changes that can fluctuate by more than 14 ft in a given 24-hour period.[5] Flow rates on the LDW are influenced by tidal cycles, storm events, and the Howard Hanson Dam, which was constructed in 1961 and is located approximately 65 mi upstream of the LDW. The dam was constructed to control water flows for two purposes. First, it provides flood control during the fall and winter, and second, it augments flows during the summer to improve fish habitat (USACE 2017). Since the construction of the dam, flows in the LDW have averaged approximately 1,340 cubic feet per second (cfs) and have rarely exceeded 12,000 cfs. Prior to dam construction, flows ranged from 15,000 to 30,000 cfs during the largest storm events (AECOM 2012). As described in the LDW RI (Windward 2010a) and FS (AECOM 2012), high-flow events and their recurrence intervals are as follows:

- 100-year high-flow event – 12,000 cfs
- 10-year high-flow event – 10,800 cfs
- 2-year high-flow event – 8,400 cfs

These LDW flow rates are the result of the combined influence of water releases from the Howard Hanson Dam and runoff into the Green River and the LDW from precipitation.

During the winter, excess water is held in the dam reservoir and released as soon as possible after a storm event to create space in the reservoir for water from the next storm event. In the spring (when the threat of flooding has passed), water is stored behind the dam until the summer months, when it is released as needed to regulate low flows (USACE 2017). Water is released from the dam on a daily basis, with daily average dam release rates[6] generally ranging from 200 to 600 cfs during the dry summer months (August and September) and from 800 to 1,200 cfs during the wet winter

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[4] Residence time is the average time a parcel of water spends in a given body of water before being exchanged (i.e., leaving that body of water).

[5] Tidal elevations are based on the Duwamish Waterway Station at Eighth Avenue South (NOAA Station ID: 9447130).

[6] Dam release rates are as measured at the US Geological Survey (USGS) gage just below the Howard Hanson Dam (Gage 12105900).

months (November to March) (USGS 2016, 2017). After big storm events with heavy precipitation, dam release rates can be much higher, well above 2,000 cfs. A dam release rate greater than 2,000 cfs has been used by King County and USGS water sampling programs to define a significant dam release (King County 2014; USGS 2016, 2017). The effect of these flow dynamics was considered in the proposed study design for surface water, which is described in Section 3.2.4.

2.2.2 Sediment

As shown in Figure 10-1 of the RI, LDW sediment includes a surface layer (i.e., the biologically active zone [BAZ]), recent sediments (i.e., sediments deposited over the past 50 years), and both an upper and lower alluvium layer. As described in the LDW RI (Windward 2010a), the BAZ refers to the upper 10 cm of the sediment where sediments are mixed by the feeding and burrowing behaviors of benthic invertebrates. Understanding the composition and mixing of this layer—which represents the sediment where the majority of benthic invertebrates reside and the primary sediment to which fish and shellfish are exposed—is a critical component of the physical CSM.

Sediment dynamics (including scour, erosion / deposition of sediment, and sediment transport) were characterized as part of the sediment transport model (STM) (QEA 2008; AECOM 2012; Windward 2010a). In addition to accounting for flows and sediment inputs from the Green River upstream of the LDW, the model estimated lateral inputs to the system (e.g., from streams, storm drains, and combined sewer overflows [CSOs]). As described in detail in the LDW FS (AECOM 2012), the STM showed that the LDW is a net depositional environment. Of the approximately 185,000 metric tons of sediment that, on average, enter the LDW from the Green River annually, an average of approximately 100,000 metric tons (54%) annually settle out in the LDW (AECOM 2012).[7] Sedimentation rates are estimated to be approximately 0.5 cm per year in the intertidal areas, 1 to 3 cm per year in most subtidal areas, and up to 30 cm per year in the turning basin from RM 4.6 to RM 4.7 (Map 2-1). The turning basin essentially acts as a trap for much of the incoming sediment from the Green River, which is the source of more than 99% of all sediment (by mass) entering the LDW. The remaining less than 1% of incoming sediment originates from streams, storm drains, CSOs, and other lateral sources. Although the lateral inputs account for only a small fraction of sediment, on average, they have higher contaminant concentrations than those in incoming sediment inputs from the upstream Green River (AECOM 2012).

As described in Section 2.3 of the FS (AECOM 2012), the STM also evaluated bed stability and the potential for scour due to ship traffic and high-flow events.

[7] Annual sediment loads in the LDW are based on the results the STM, as presented in the LDW FS (AECOM 2012), which are based on the 10-year STM simulation results.

- **Scour from passing ships** – Scour from passing ships traveling at typical rates of speed (2 to 3 knots[8]) is not expected to exceed 1 cm in any area of the LDW (AECOM 2012). For ships traveling at the LDW speed limit of 5 knots, average scour is expected to range from 1 to 2 cm in Reach 1, and less than 1 cm in Reaches 2 and 3.
- **Localized ship scour –** In addition to scour from passing ships, localized scour associated with vessels (primarily tugs maneuvering large vessels such as barges or cargo ships) can occur in active berthing areas (AECOM 2012). Scour marks in the LDW range in depth from a few centimeters to more than 30 cm, although most are less than 10 cm in depth (Map 2-2) (AECOM 2012).
- **Scour from high-flow events** – During extreme events, net erosion is expected in some areas of the LDW, with the highest erosion rates occurring upstream of RM 2.8 (Map 2-3). For example, during a high-flow event with a 100-year return interval, the STM predicts that net erosion occurs in 18% of the LDW, generally to a depth of 10 cm below the sediment surface (and to no more than 22 cm below the sediment surface) (AECOM 2012). Most areas subject to these high-flow scour events are net depositional on longer timescales (Map 2-1).

Together, the various actions that contribute the disturbance of bedded sediment (scour and erosion, as well as natural processes such as bioturbation) result in the incoming sediment being mixed with older bedded sediments (AECOM 2012). The depth of this mixing varies as described above, but primarily occurs within the BAZ (i.e., the top 10 cm of the sediment).

2.3 Contaminant Concentrations

The physical processes described above are important in understanding the distribution of contaminant concentrations (and how they may change) in sediment and water. These patterns, along with characteristics such as the amount of organic carbon present in LDW sediments and suspended solids,[9] influence how organisms in the LDW (such as benthic invertebrates, shellfish, and fish) are exposed to contaminants, and how contaminants bioaccumulate in tissue directly from sediment, porewater, and surface water, as well as via the food chain.

The patterns in the spatial and vertical distributions of contaminants in sediment result from interactions among a variety of factors, including the proximity and magnitude of contaminant sources (particularly historical sources), as well as the physical processes described in Sections 2.2 (i.e., surface layer dynamics, transport and deposition of sediment within the LDW over time, and localized conditions that affect sediment

[8] Typical rates of speed for ships in the LDW are based on the information reported from personal communications in the LDW FS (AECOM 2012).

[9] The average total organic carbon (TOC) content in LDW sediments is 1.9%, as reported in the LDW RI (Windward 2010a).

mixing such as scour and resuspension). Thus, sources (both historical and recent) and the sediment dynamics described above are important in understanding the current patterns of contaminant concentrations in sediment and how they are predicted to change.

Overall, sediment remedial actions that have been conducted in the LDW, source control efforts, and incoming cleaner sediment from the Green River are resulting in decreasing contaminant concentrations in sediment. These concentrations are predicted to continue to decrease in the years to come as a result of several factors, including sediment remediation, source control actions, and sediment inputs from upstream (AECOM 2012).

Contaminant concentrations in water (both filtered and unfiltered) have greater temporal variability than those in sediment. Causes of this variability can include river conditions related to flow rates based on dam releases and recent precipitation. For example, Green River surface water data analyzed for polychlorinated biphenyls (PCBs) highlight the importance of dam releases, as well as local precipitation events (both the day of and prior to sampling[10]), in affecting PCB concentrations in water (King County 2014; Windward 2010a).

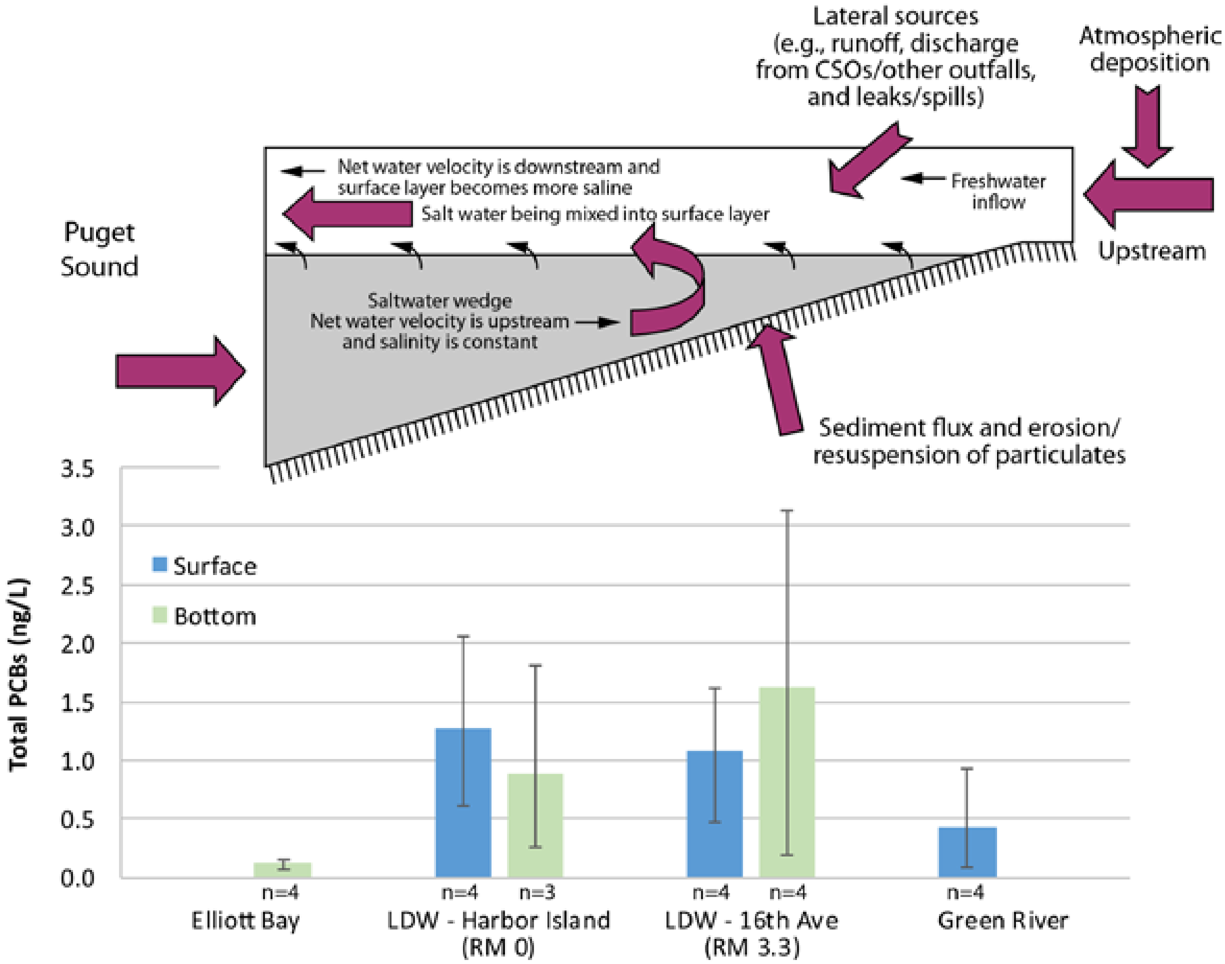
Concentrations of PCBs detected in surface water samples collected from the Green River during periods of rainfall without significant dam releases (i.e., dam release rates less than 2,000 cfs) were higher than concentrations in samples collected during baseflow conditions[11] (both wet and dry) and during times when significant dam releases were occurring. This was particularly true during storm events (defined as more than 0.25 in. of rainfall during a 24-hour period) when significant dam releases were not occurring, a condition that happens most frequently in the early fall (September / October) (King County 2014). Similar patterns were observed by King County for polycyclic aromatic hydrocarbons (PAHs), while other contaminants such as arsenic were not found to have higher concentrations during storm events (King County 2014).

Figure 2-3 presents a conceptual model for PCB transport in the LDW, along with a graphic of total PCB concentrations in LDW surface water samples collected by King County in 2005 (Mickelson and Williston 2006). In this model, PCB concentrations detected in LDW surface waters are affected by flow rates as well as estuarine circulation. Higher PCB concentrations have been detected in the bottom layer of the LDW at RM 3.3 than at RM 0, possibly due to the increased residence time of bottom

[10] The influence of precipitation events prior to sampling is dependent on the duration of the storm event.

[11] Baseflow conditions are defined as average seasonal flow rates. As described in Section 2.2.1, average dam release rates generally range from 200 to 600 cfs during the dry summer months (August and September) and from 800 to 1,200 cfs during the wet winter months (November to March) (USGS 2016, 2017). Dam release rates are as measured at the USGS gage just below the Howard Hanson Dam (Gage 12105900).

water and flux from sediment farther upstream. The PCB concentrations in the surface layer increase from upstream to downstream (Figure 2-3), likely reflecting greater cumulative mixing with the bottom water (Stern 2015). In addition, lateral sources influence surface layer concentration patterns.



Data source: Mickelson and Williston (2006).

Figure 2-3. Simplified conceptual model of PCB transport in LDW surface water

In contrast to the longitudinal (upstream versus downstream) distribution of concentrations within the LDW, the available data suggest minimal differences in lateral distribution (i.e., from shoreline to shoreline) of contaminant concentrations, indicating that the waterway is laterally well mixed. As presented in the LDW RI (Windward 2010b), King County collected water samples from October 1996 to June 1997 for the analysis of metals and semi-volatile organic compounds (SVOCs) from transects across the LDW as part of its water quality assessment (King County 1999).

The metals[12] data suggested that differences in concentrations across the waterway were small, even in transects located near large CSOs.[13]

In addition, as part of sampling conducted by King County in 2011 and 2012 in the Green River (near the Foster Links golf course in Tukwila, Washington), chemical and conventional parameter concentrations in samples collected from the west side of the river (where the majority of samples were collected) were compared with those in composite water samples collected in a transect across the river. Concentrations in these samples were found to be similar between the two sampling methods for all but PCBs, indicating that the Green River is well mixed (King County 2014). Total PCB concentrations in samples collected from the west side of the Green River using the auto-sampler were higher than those in the cross-river composite samples (King County 2014). However, later investigations indicated that this difference was almost entirely due to auto-sampler equipment PCB contamination rather than differences in concentrations in the river (Leidos 2016).[14]

[12] SVOCs were infrequently detected, so this evaluation could not be conducted for these contaminants. Other chemicals (e.g., PCBs) were not analyzed throughout the monitoring period because they were not detected during early sampling events.

[13] Sampling did not specifically target CSO discharge events, although some discharge event data were included in this dataset.

[14] King County is currently conducting a study to isolate the source of the PCBs from the auto-sampler equipment. Data indicate the source to be the type of silicone tubing used (Williston et al. 2016).

3 Tasks

Tasks 2 through 10 are described in this section, including the purpose of each task and its design and rationale. These tasks are defined in accordance with the statement of work in the third AOC amendment (EPA 2016).

3.1 Task 2: Existing Data Compilation

The purpose of Task 2 is to identify, review, compile,[15] and summarize LDW and upstream data collected since the RI/FS (Windward 2010a; AECOM 2012). As described in the third AOC amendment (EPA 2016), Task 2 involves compilation of data collected from 2010 to 2016 and compilation of data collected after 2016,[16] including data collected as part of the pre-design studies. As described in Appendix C of this work plan, these data will be incorporated into the LDW database.

In the first step of Task 2, a *Technical Memorandum: Compilation of Existing Data* (hereafter referred to as the data compilation memorandum) was prepared, as described below, and submitted to EPA (Windward and Integral 2017b). The compiled data (Appendix C of the data compilation memorandum) included the following:

- **LDW data** – Sediment, tissue, surface water, porewater, and seeps
- **Upland data** – Storm drain and combined sewer system source tracing solids data from the LDW drainage basin and groundwater[17] and bank soil data from adjacent upland areas
- **Upstream data** – surface water and suspended solids

The third amendment to the AOC (EPA 2016) stated that only data obtained or made available since April 2010 were to be compiled. However, it was not always possible to determine when the data were obtained or made available; therefore, any data collected in or after 2010 were targeted to collect all relevant data not already in the RI/FS dataset.[18] The temporal and spatial scopes of the data are summarized in Table 3-1.

[15] Data compiled as part of Task 2 will ultimately be incorporated into the LDW database.

[16] Only data that are made available for the duration of the pre-design studies will be compiled.

[17] The groundwater data were submitted as part of a separate compilation (see Section 4).

[18] A search was conducted for pre-2010 data from EAA monitoring events that were not included in the RI/FS; no data were identified.

Table 3-1. Data compilation scope

Medium	Spatial Extent	Date Range[a]	Data Quality Review Required per AOC
In-waterway Data			
Sediment[b]	RM 0 to RM 5 of the LDW	collected in or after 2010[c]	yes
Surface water			
Tissue			
Porewater			
Seep			
Upland Data			
Bank soil	RM 0 to RM 5 along the banks of the LDW	collected in or after 2010	no
Storm drain/combined sewer system solids	drainage basins discharging to the LDW		
Groundwater[d]	wells closest to the LDW	most recent data collected	
Upstream Data			
Suspended solids – chemistry and particle size distribution	Green/Duwamish River at Foster Links (RM 10)	collected in or after 2010	no
Surface water			

a Data were included in the draft data compilation memorandum if they were made available prior to December 20, 2016. Additional data will be compiled during the pre-design studies as appropriate.

b Surface and subsurface sediment.

c No pre-2010 data from EAA monitoring events were identified that were not already in the FS database.

d Groundwater data were submitted as part of a separate compilation.

AOC – Administrative Order on Consent
EAA – early action area
FS – feasibility study
LDW – Lower Duwamish Waterway
MHHW – mean higher high water
MLLW – mean lower low water
RM – river mile

Available data were acquired from LDWG, Ecology's Environmental Information Management (EIM) database, and Ecology during the drafting of the data compilation memorandum.

The LDW data (i.e., sediment, tissue, surface water, porewater, and seep data collected from the LDW site) underwent a data quality review to determine if they met data quality objectives (DQOs) consistent with those developed for the RI/FS using Superfund guidance. If so, the data were summarized, compiled in the LDW dataset, and determined acceptable for all uses. If LDW data did not meet DQOs, they were summarized, compiled in the LDW database, and flagged for conditional use. For example, data from the EIM database did not meet DQOs because quality control (QC) backup was not available. Data (including surface and subsurface sediment and porewater data) collected at locations that were subsequently dredged or remediated were excluded from the compilation.

Upstream data (i.e., surface water and suspended solids) and adjacent LDW data (i.e., groundwater, storm drain/combined sewer system solids, and bank soils) collected since January 2010 were also summarized and compiled in the database. Data reviews were not conducted, per the AOC, but an overview of any available data quality information was provided. These data were flagged for conditional use.

All of the Task 2 data acquired to date were presented in Appendix C of the draft data compilation memorandum. This appendix contained tables summarizing the sources and types of data, sampling years, numbers of samples, and data quality reviews (if conducted) (Windward and Integral 2017b). Figures showing data locations (relative to RI/FS data locations), outfall locations, in- and over-water structures, and property lines were included.

The data compilation memorandum (Windward and Integral 2017b) also provided an overview of the following studies:

- EPA Regional Applied Research Effort (RARE), which involved a study of inorganic arsenic bioaccumulation in clam tissue, and the potential relationship with sediment, surface water, and porewater
- Massachusetts Institute of Technology (MIT) study, which is using polyethylene (PE) passive samplers to estimate freely dissolved PCB concentrations in LDW surface water and porewater in an attempt to better understand the relationship among PCB concentrations in surface water, surface sediment, and porewater
- LDWG ENR/AC pilot study, which is assessing the potential effectiveness of AC in combination with the placement of an ENR layer to reduce the bioavailability of PCBs in sediment in the LDW

All of these studies have been designed, in part, to assess the relationships among concentrations in tissue, sediment, or porewater. The data from these studies were not available when the draft data compilation memorandum was prepared; therefore, an overview was provided rather than an analysis of the data. These data were evaluated as part of the porewater addendum (Appendix E).

As described in Appendix C of this work plan, the data from these three studies (in addition to relevant and acceptable data collected over the course of this project) will be incorporated into the LDW database when available.

3.2 Task 3: Quality Assurance Project Plans

The DQOs, conceptual study designs, and general sampling and analytical methods for baseline sediment, tissue, surface water, and source-related sediment (near-outfall sediment and bank soils) and seep sampling efforts are discussed in this section. A

QAPP will be prepared for each of the sample media,[19] which are described in the following subsections. The QAPPs will each contain a table briefly summarizing the approach in terms of the seven-step DQO process (EPA 2006).

Porewater is discussed in an addendum to this work plan (Appendix E). The addendum presents porewater DQOs and the need for additional data collection based on existing data, data being collected for other studies, and the objectives of the pre-design studies. The conceptual design for the porewater data collection effort is described in the addendum, which references which QAPP will present detailed porewater study designs.

3.2.1 Sediment QAPP

This section outlines the components of the sediment QAPP. The LDW ROD establishes cleanup levels for sediment that include two sediment compliance intervals (EPA 2014):

- Surface sediment from the 0–10-cm interval throughout the LDW for RAOs 1, 2 (netfishing), 3,[20] and 4
- Sediment from the 0–45-cm interval in relevant[21] intertidal areas for RAO 2 (clamming and beach play)

Regarding sediment sample collection, the third amendment to the AOC (EPA 2016) directs the following:

- The collection of 0–10-cm interval sediment samples for site-wide baseline characterization
- The collection of 0–45-cm interval sediment samples in clamming areas and beach play areas for baseline characterization
- The collection of individual 0–10-cm sediment samples to assist in identifying site-wide trends and changes in surface sediment quality over time in MNR areas,[22] and for archival in case additional PCB congener data are needed
- The collection of 0–10-cm sediment samples near outfalls in uncharacterized areas to assist in Ecology's source control efforts
- The collection of bank samples in uncharacterized, erodible areas to assist in Ecology's source control efforts

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[19] QAPPs for surface water and fish and crab sampling have been prepared and approved by EPA in parallel with this work plan (see Section 4).

[20] The compliance interval for RAO 3 is 0–10 cm. Compliance with RAO 3 will be assessed as part of design and post-remedy monitoring.

[21] Clamming areas and beach play areas were identified in the RI (Windward 2010a).

[22] It is acknowledged that the remedial boundaries and technology assignments portrayed in ROD Figure 18, titled *Selected remedy*, are likely to change following design. Thus, any reference to MNR areas in this work plan refers to preliminary MNR areas.

Each of these efforts is discussed separately in the following subsections.

3.2.1.1 Baseline surface sediment for site-wide RAOs (0–10 cm)

The DQOs for the establishment of baseline conditions in 0–10-cm LDW surface sediment samples are as follows:

- To establish baseline, site-wide 95% upper confidence limit for the mean (95UCL) concentrations of RAOs 1, 2, and 4 risk drivers[23]
- To establish a baseline, site-wide spatially weighted average concentration (SWAC) to serve as the foundation for assessing trends from before to after sediment remediation for RAO 1, 2, and 4 risk drivers

The baseline surface sediment sample design is tailored to the DQOs above; baseline for RAOs 1, 2, and 4 will be established based on data from a single site-wide sampling event. Sediment sampling can then be repeated over time to generate comparable datasets to assess progress toward cleanup goals, and to assess the effectiveness of the remedy in attaining the site-wide RAOs. Baseline concentrations will reflect the combined effects of 1) cleanup actions at approximately 29 ac of EAAs, 2) ongoing source control, and 3) ongoing natural recovery throughout the LDW. Site-wide SWAC comparisons over time will establish trends in sediment concentrations, while the 95UCL is the ROD compliance metric for surface sediment (EPA 2014).

Study Design and Rationale

The sampling design for baseline surface sediment was developed based on a statistical evaluation to ensure representative coverage of the LDW (Appendix A). To ensure that baseline surface sediment data are evenly distributed throughout the waterway, a set of irregularly shaped grid cells of approximately equally sized areas was established, and a sample location was randomly selected within each grid cell[24] (Map 3-1). Because each sample is representative of an equal area, the arithmetic average will be the same as the SWAC, and the calculation of the 95UCL will be straightforward.

The number of grid cells selected to characterize the site-wide average (as SWAC and 95UCL) was based on simulated variance estimates and EPA direction.

Post-remedy variance was estimated using surface sediment data for PCBs[25] from MNR areas in the LDW as designated in Figure 18 of the ROD (EPA 2014).[26] The simulations

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[23] Risk drivers are PCBs, dioxins/furans, carcinogenic polycyclic aromatic hydrocarbons [cPAHs], and arsenic (ROD Table 19, titled *Cleanup levels for PCBs, arsenic, cPAHs, and dioxins/furans in sediment for human health and ecological COCs [RAOs 1, 2, and 4]*). PCBs are the only risk drivers for RAO 4. RAO 3 is discussed in Section 3.2.1.2.

[24] Ten of the samples were not randomly selected; rather, they were placed to reoccupy existing locations (see Section 3.2.1.2).

[25] Sediment data for the other three risk drivers, arsenic, cPAHs, and dioxins/furans, were also reviewed. The PCB data had the highest variability, so they were used in the sampling design to be conservative (see Appendix A).

presented in Section 2 of Appendix A do not include data from any areas slated for active remedies (i.e., dredging, capping, or enhanced natural recovery [ENR]). So while the MNR dataset used for these simulations is expected to approximate or overestimate the variability post-remediation, it is likely to underestimate the population variance that may be seen during the baseline sampling period. The simulations are expected to overestimate the population variance following implementation of the remedy, which will reduce variance in sediment concentrations throughout the LDW since clean sand will be the post-remediation surface in all active remedy areas. A spatially explicit bootstrapping approach was used to simulate variability and the distributional form of the data expected from the proposed sampling design. For each of the bootstrap samples (B = 10,000), goodness-of-fit tests were run to identify whether the results were best described by a normal or gamma distribution, and the variability (i.e., the coefficient of variation [CV]) within each bootstrap sample was calculated. The distribution of the CVs across the 10,000 bootstrap replicates was used to identify the expected and upper bound on the variability from the actual post-remediation environment.

While the data used in these simulations are dated and limited in certain areas, the results from the simulations provide an approximation of the relative variance that may be expected during post-remediation sampling. Using a CV value that exceeded the maximum value observed in the simulations, an approach of 140 samples combined into 20 composite samples was proposed. After reviewing this proposed approach and considering the limitations of the dataset on which it was based, EPA directed that a more conservative assumption about variance be used resulting in an approach with 24 composite samples of 7 samples each (for a total of 168 field samples). This approach, which uses an irregular grid of 168 cells of approximately equal area, is expected to result in a relative margin of error (RME)[27] for the mean of 25% or lower, which is less than analytical variability.[28]

One sample was randomly placed in each of the 168 cells using a geographic information system (GIS) with a spatial requirement that the sample locations must be at least 150 ft[29] from one another to minimize spatial autocorrelation (Appendix A). Once collected, the surface sediment samples from these 168 cells will be combined into 24 composite samples for analysis (Map 3-2), and individual samples will be retained in archive for analysis as needed. Each composite sample will contain seven samples. The

[26] It is acknowledged that the remedial boundaries and technology assignments portrayed in ROD Figure 18, titled *Selected remedy*, are likely to change following design.

[27] RME is measured as the width of the 95UCL as a percent of the mean.

[28] The analytical precision required by EPA functional guidelines for the analytical methods typically used in sediment characterization ranges from 20 to 50%, comparable to a range of 16 to 42% for RME as defined for this project.

[29] This minimum separation distance was reduced from the 200 ft used in Appendix A because the sampling grids are smaller.

analysis of composites is a statistically efficient and cost-effective approach to characterize site-wide concentrations. The composite areas and the remedy technology assignments (as preliminarily mapped in the ROD) are provided in Map 3-3.

In future years of monitoring, the number of samples per composite should remain consistent to maintain year-to-year comparability of the datasets. The numbers of field samples and composite samples may change in response to updated information about site variance, and to achieve a desired RME for the site-wide mean. In this way, a robust site-wide SWAC and 95UCL can be calculated for each sampling event.

Sampling and Analytical Methods

Surface sediment samples will be collected as 0–10-cm grab samples[30] following the RI sediment investigation methods (Windward 2006), which are consistent with surface sediment standardized collection and processing procedures for the Puget Sound area (PSEP 1997). These samples will be composited as described above.

The surface sediment composite samples will be analyzed for the contaminants of concern (COCs) for RAOs 1, 2, and 4 (PCBs, total arsenic, cPAHs, and dioxins/furans) (ROD Table 19) (EPA 2014) and conventional parameters, including TOC, grain size, and total solids. Black carbon will also be analyzed. The analytical methods and associated RLs for each COC are presented in Table 3-2 and compared to the cleanup levels for each of the RAOs. The analytical methods for the conventional parameters are provided in Appendix B.

Table 3-2. RAO 1, 2, and 4 COCs and associated RLs and cleanup levels for baseline site-wide surface sediment (0–10-cm) composite samples

COC	Method	Unit	RL	Cleanup Levels[a]		
				RAO 1	RAO 2	RAO 4
PCBs	EPA 8082A (Aroclors)[b]	µg/kg dw	20	2	1,300	128
	EPA 1668C (congeners)	µg/kg dw	0.0004[c]			
Total arsenic	EPA 6020A	mg/kg dw	0.500	na	7	na
cPAH	EPA 8270D-SIM	µg TEQ/kg dw	4.5[d]	na	380	na
Dioxins/furans	EPA 1613B	ng TEQ/kg dw	1.14[e]	2	37	na

a All of these cleanup levels for surface sediment (0–10 cm) are LDW-wide values with a 95UCL compliance measure.

b If none of the PCB Aroclors are detected in a sample, then the sample will be submitted for analysis of PCB congeners.

c The PCB RL is based on the LMCL from Axys and represents the maximum value for an individual PCB congener. Individual congener LMCLs are listed in Appendix B. The reported LMCL will be adjusted based on the mass of each sample.

30 Surface sediments will be collected from each location using a double 0.1-m^2 van Veen grab sampler from a sampling vessel, if feasible. Some intertidal locations may be too shallow to access from a sampling vessel, in which case surface sediments will be sampled from the shoreline during low tide.

[d] The RL for the cPAH TEQ value was calculated using one-half the RL for each of the cPAH compounds and the appropriate TEF values (California EPA 2009).

[e] The dioxin/furan RL is based on the laboratory minimum calibration level from Axys; the dioxin/furan mammalian TEQ value was calculated using one-half the RL for each dioxin/furan compound and appropriate mammal TEF values (Van den Berg et al. 2006).

95UCL – 95% upper confidence limit for the mean
Axys – Axys Analytical Services, Ltd.
COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
EPA – US Environmental Protection Agency
LDW – Lower Duwamish Waterway
LMCL – lower method calibration limit
na – not applicable
PCB – polychlorinated biphenyl
RAO – remedial action objective
RL – reporting limit
SIM – selective ion monitoring
TEF – toxic equivalency factor
TEQ – toxic equivalent

Based on the comparison with cleanup levels, all of the RLs are sufficient. For PCBs, the PCB Aroclor method (EPA 8082A) RL of 20 µg/kg dry weight (dw) is higher than the RAO 1 cleanup level of 2 µg/kg dw. However, PCBs in baseline sediment samples are likely to be detected at concentrations above 20 µg/kg dw, since they were detected in 94% of the 1,390 sediment samples in the FS dataset using the PCB Aroclor method. If none of the PCB Aroclors are detected in a particular composite sample, then that sample will be analyzed for PCB congeners with a method RL of 0.004 µg/kg dw.[31]

3.2.1.2 Individual 0–10-cm sediment samples

The DQOs for the collection and analysis of individual LDW surface sediment samples (0–10 cm) are as follows:

- To compare (on a point-by-point basis) concentrations in baseline samples collected from within MNR areas to the (benthic) cleanup levels presented in ROD Table 20[32] (EPA 2014)
- To support the evaluation of site-wide trends and comparisons of concentrations to predicted natural recovery in MNR areas[33]

A subset (20) of the surface sediment grab samples that are located in MNR areas (described in Section 3.2.1.1) will be analyzed for RAO 3 COCs.

Characterization relative to RAO 3 and location-specific evaluations of MNR status and progress will be addressed during design and long-term monitoring (see Table 1-1 and

[31] The PCB RL is based on the laboratory minimum calibration level (LMCL) from Axys Analytical Services, Ltd. (Axys) and represents the maximum value for an individual PCB congener. Individual congener LMCLs are listed in Appendix B. The reported LMCL will be adjusted based on the mass of each sample.

[32] ROD Table 20 is titled *Sediment cleanup levels for ecological (benthic invertebrate) COCs for RAO 3*. MNR areas are preliminary because remedial boundaries and technology assignments portrayed in ROD Figure 18, titled *Selected remedy*, are likely to change during remedial design.

[33] Concentrations are not expected to meet natural recovery predictions during baseline sampling because the projections are for 10 years post-remedy.

Appendix D). The data collected as part of the pre-design studies are not being collected to delineate MNR areas or to assess MNR area compliance.

Study Design and Rationale

Of the 168 locations sampled for the composite samples (Map 3-1),[34] a subset of 20 individual locations in MNR areas (based on ROD Figure 18 (EPA 2014)) will be used for this analysis. Ten of these locations[35] will reoccupy LDW RI/FS surface sediment locations in MNR areas with sediment cleanup objective (SCO) exceedances based on existing data; these locations will constitute fixed station locations that will be resampled during future monitoring events. The other 10 locations will be selected randomly in MNR areas to characterize the range of conditions in the MNR areas. These 20 samples will be analyzed for the target analytes in Table 3-3, with archives retained for potential congener analyses as described in the next subsection. The samples from these 20 locations will constitute a split-panel sampling design for measuring statuses and trends in the MNR areas.

Table 3-3. RAO 3 COCs and associated RLs and cleanup levels for individual 0–10-cm sediment samples

COC	Method	RL	Cleanup Levels for RAO 3[a]
Metals (mg/kg dw**)**			
Arsenic	EPA 6020A	0.500	57
Cadmium	EPA 6020A	0.100	5.1
Chromium	EPA 6020A	0.500	260
Copper	EPA 6020A	0.500	390
Lead	EPA 6020A	0.100	450
Silver	EPA 6020A	0.200	6.1
Zinc	EPA 6020A	4.00	410
Mercury	EPA 7471B	0.025	0.41
PAHs and SVOCs (µg/kg dw**)**			
Benzo(a)anthracene	EPA 8270D	20.0	2,200[b]
Benzo(a)pyrene	EPA 8270D	20.0	1,980[b]
Total benzofluoranthenes	EPA 8270D	40.0	4,600[b]
Chrysene	EPA 8270D	20.0	2,200[b]
Dibenzo(a,h)anthracene	EPA 8270D	20.0	240[b]
Indeno(1,2,3-cd)pyrene	EPA 8270D	20.0	680[b]
Anthracene	EPA 8270D	20.0	4,400[b]
Acenaphthene	EPA 8270D	20.0	320[b]
Benzo(g,h,i)perylene	EPA 8270D	20.0	620[b]

[34] Actual baseline locations will be selected in the sediment QAPP.

[35] Because these samples also will contribute to the composite design to address DQOs for RAOs 1, 2, and 4 (see Section 3.2.1.1), the number of fixed locations was restricted to limit bias in the site-wide mean estimate.

COC	Method	RL	Cleanup Levels for RAO 3[a]
Fluoranthene	EPA 8270D	20.0	3,200[b]
Fluorene	EPA 8270D	20.0	460[b]
Naphthalene	EPA 8270D	20.0	1,980[b]
Phenanthrene	EPA 8270D	20.0	2,000[b]
Pyrene	EPA 8270D	20.0	20,000[b]
Total HPAHs	EPA 8270D	40.0	19,200[b]
Total LPAHs	EPA 8270D	20.0	7,400[b]
2,4-dimethylphenol	EPA 8270D-SIM	25	29
2-methylnaphthalene	EPA 8270D	20.0	760[b]
4-methylphenol	EPA 8270D	20.0	670
Benzoic acid	EPA 8270D-SIM	100	650
Benzyl alcohol	EPA 8270D-SIM	5	57
Bis(2-ethylhexyl)phthalate	EPA 8270D	50.0	940[b]
Butyl benzyl phthalate	EPA 8270D	20.0	98[b]
Dibenzofuran	EPA 8270D	20.0	300[b]
Dimethyl phthalate	EPA 8270D	20.0	1,060[b]
Hexachlorobenzene	EPA 8270D-SIM	5.0	7.6[b]
n-Nitrosodiphenylamine	EPA 8270D-SIM	5	220[b]
PCP	EPA 8270D-SIM	20	360
Phenol	EPA 8270D	20.0	420
1,2,4-trichlorobenzene	EPA 8270D-SIM	5.00	16.2[b]
1,2-dichlorobenzene	EPA 8270D-SIM	5.00	46.0[b]
1,4-dichlorobenzene	EPA 8270D -SIM	5.00	62.0[b]
PCBs (µg/kg dw**)**			
PCBs	EPA 8082A (Aroclors)[c]	20.0	240[b,c,d]

a Per the ROD (EPA 2014), cleanup levels for RAO 3 are based on the benthic SCO chemical criteria in the SMS (WAC 173-204-562). The compliance depth is the 0–10-cm interval.

b Organic carbon-normalized criteria were converted to non-normalized values using 2% TOC. Cleanup levels are assessed on organic carbon normalized basis. These values are presented as dry weight values for purposes of comparing to RLs only.

c If none of the PCB Aroclors are detected, then the sample will be submitted for analysis of PCB congeners by Method 1668C with an estimated RL of 0.0004 µg/kg dw. The PCB RL is based on the LMCL from Axys and represents the maximum value for an individual PCB congener. Individual congener LMCLs are listed in Appendix B. The reported LMCL will be adjusted based on the mass of each sample.

d All discrete 0–10-cm samples analyzed for PCB Aroclors will be archived for potential PCB congener analysis, as discussed in Section 3.2.1.3.

Axys – Axys Analytical Services, Ltd.
COC – contaminant of concern
dw – dry weight
EPA – US Environmental Protection Agency
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LMCL – lower method calibration limit
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PCP – pentachlorophenol
RAL – remedial action level
RAO – remedial action objective
RL – reporting limit
ROD – Record of Decision
SCO – sediment cleanup objective
SIM – selective ion monitoring
SMS – Washington State Sediment Management Standards
SQS – sediment quality standards
SVOC – semivolatile organic compound
TOC – total organic carbon
WAC – Washington Administrative Code

Sampling and Analytical Methods

Sediment grab samples will be collected using the methods described in Section 3.2.1.1. For locations identified for the analysis of individual samples, the collected sediment will be split; a portion will be collected for an analysis of the individual samples, and a portion will be combined into the composite sample for site-wide RAOs.

The analytical methods proposed for each of the COCs in ROD Table 20 (EPA 2014) are provided in Table 3-3. The method RLs for each COC are compared to the cleanup levels for RAO 3. The cleanup levels for many organic contaminants are organic carbon-normalized values. For the purposes of this comparison, the cleanup levels were converted to dry weight concentrations assuming 2% TOC. Based on this comparison, all of the methods are expected to be sufficiently sensitive for the results to be compared to the cleanup levels. Black carbon will also be analyzed in each of the samples.

3.2.1.3 Evaluation of relationship between total PCBs as sum of Aroclors and total PCBs as sum of congeners

The DQO for the PCB Aroclor versus congener sum evaluation is as follows:

- To assess the relationship between total PCBs based on the sum of detected congeners versus the sum of detected Aroclors in LDW sediment

To assess this DQO, the existing RI/FS and post-2010 (Task 2) data will be reviewed in the sediment QAPP to identify sediment samples analyzed for both PCB Aroclors and PCB congeners. These data will be evaluated to determine if total PCBs calculated using an Aroclor sum and a PCB congener sum appear to be reliably correlated throughout the concentration range sampled. Particular focus will be on the lower concentration range, because the post-remedial PCB concentrations will be lower than the current PCB concentrations.

The relationship based on existing data will be evaluated to ensure that there are sufficient data distributed throughout the concentration range, and to determine whether there are potential outliers at the extremes of the concentration range. If additional data are determined to be necessary, then the total PCB concentrations calculated as the sum of Aroclors in the individual sediment samples analyzed for RAO 3 COCs will be evaluated to determine if any of the samples are suitable for PCB congener analysis.[36] This determination will support the development of a relationship between PCB congener and Aroclor sums.

3.2.1.4 Intertidal baseline sediment for direct contact RAO 2 - clamming and beach play (0–45-cm)

The DQOs for the collection and analysis of surface sediment samples (0–45 cm) for RAO 2 are as follows:

[36] These samples will be archived for potential PCB congener analysis.

- To establish baseline 95UCL concentrations of human health risk drivers for RAO 2 across all potential clamming areas identified in the ROD
- To establish baseline site-wide clamming area mean concentrations to assess trends following sediment remediation for RAO 2 (direct contact – clamming) risk drivers
- To establish baseline 95UCL concentrations for risk drivers to achieve RAO 2 in each of the eight beach areas
- To establish baseline beach area-specific mean concentrations to assess trends following sediment remediation for RAO 2 (direct contact – beach play) risk drivers

Clamming Areas

Potential clamming areas identified in the RI (Windward 2010a) will be sampled to assess baseline conditions in these intertidal areas throughout the LDW. Seventy-one locations will be sampled (Map 3-4), and three separate samples will be collected from each of these locations (in close proximity to each other) for a total of 213 samples. One of the three samples from each location will be included in one of three site-wide composite samples, each representing LDW-wide potential clamming areas.

The total number of locations (71) was determined based on the requirements that every potential clamming area be sampled, and that the number of sampling locations within each area be approximately proportional to the size of the area. In practice, one sampling location is placed in each of the smallest clamming areas, and a proportionally larger number of sampling locations is placed in the larger potential clamming areas. When a clamming area has more than one sampling location, those locations are spatially balanced within the clamming area to avoid clustering. This approach results in a total of 71 sampling locations in clamming areas throughout the LDW (Map 3-4). As an example, the smallest intertidal area is 1.5 ac and has one sampling location, and the largest intertidal area (surrounding Kellogg Island) is approximately 29.7 ac and has 19 sample locations. As will be further discussed in the sediment QAPP, the number of samples in each sampling area is proportional to its physical area, with an average of one sample per 1.3 ac in each of the intertidal areas (Map 3-4).

The concentrations in the three composite samples will be used to estimate the potential clamming area-wide mean, and the variance among the composite samples will be used to calculate the site-wide clamming area 95UCL. A discussion of the 95UCL calculation is provided in Appendix A (Section 3.2). In future monitoring, the locations of the 71 samples in the intertidal clamming areas will be re-randomized to allow unbiased inference about potential clamming area-wide conditions at each point in time.

Sampling and Analytical Methods

At each location shown on Map 3-4, three sediment samples will be collected for a total of 213 sediment samples. Each sediment sample will be collected from the perimeter of a hole dug to 45 cm deep. The sample will be collected using a stainless steel spoon, and a concerted effort will be made to sample an equal volume throughout the 45-cm depth. The samples will then be combined to create three site-wide composite samples, each of which will each contain 71 samples. The details of the compositing protocols will be provided in the surface sediment QAPP.

Each of the 0–45-cm composite samples will be analyzed for human health direct contact COCs (PCBs, total arsenic, cPAHs, and dioxins/furans) identified in ROD Table 19 (EPA 2014) (Table 3-4). In addition to these COCs, ROD Table 14[37] identified toxaphene as a direct contact contaminant of potential concern (COPC). Toxaphene was not identified as a COC because of its low percent contribution to cumulative excess cancer risk (6% or less) and low detection frequency in surface sediment samples (1%). Available analytical methods for toxaphene have not been sufficiently sensitive to assess this compound in sediment. The methods will be reviewed in the sediment QAPP in order to determine whether to analyze this contaminant.

Table 3-4. RLs and cleanup levels for sediments analyzed for direct contact COCs

COC	Method	Unit	RL	Cleanup Levels for RAO 2[a]	
				LDW-wide Clamming Areas	Individual Beaches
PCBs	EPA 8082A (Aroclors)[b]	µg/kg dw	20	500	1,700
Total arsenic	EPA 6020A	mg/kg dw	0.500	7	7
cPAH	EPA 8270D-SIM	µg TEQ/kg dw	4.5[c]	150	90
Dioxins/furans	EPA 1613B	ng TEQ/kg dw	1.14[d]	13	28
Toxaphene[e]	EPA 8081A	µg/kg dw	25	na	na

Source: Adapted from ROD Table 19 (EPA 2014).

a The compliance depth is 0–45 cm, and the 95UCL is the compliance measure on each spatial scale.

b If none of the PCB Aroclors are detected in a sample, then the sample will be submitted for analysis of PCB congeners by Method 1668C with an estimated RL of 0.0004 µg/kg dw.

c The RL cPAH TEQ value was calculated using one-half the RL for each of the cPAH compounds and the appropriate TEF values (California EPA 2009).

d The dioxin/furan RL is based on the laboratory minimum calibration level from Axys; the dioxin/furan mammalian TEQ value was calculated using one-half the RL for each dioxin/furan compound and appropriate mammal TEF values (Van den Berg et al. 2006).

e ROD Table 14 identified toxaphene as a direct contact COPC.

95UCL – 95% upper confidence limit for the mean
Axys – Axys Analytical Services, Ltd.
dw – dry weight
COC – contaminant of concern
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
EPA – US Environmental Protection Agency
LDW – Lower Duwamish Waterway
na – not applicable
PCB – polychlorinated biphenyl
RAO – remedial action objective
RL – reporting limit
ROD – Record of Decision
SIM – selective ion monitoring
TEF – toxic equivalency factor
TEQ – toxic equivalent

[37] ROD Table 14 is titled *Summary of COPCs and rationale for selection as COCs for human health exposure scenarios*.

Beach Play Areas

To assess baseline conditions at the eight beach areas identified in the RI (Windward 2010a) (Map 3-5), three composite samples will be analyzed from each beach area. The variance among the composite samples will be used to calculate a 95UCL for each beach area (see Section 3.1 in Appendix A for more information). Similar to the potential clamming area sampling approach, at each of the beach play sampling locations, three separate samples will be collected within several feet of one another. In this way, sediment from each location will contribute to each of the three composite samples per beach area, and the three composites will represent field replicates of the beach-wide mean, capturing small-scale spatial variability as well as sampling and analytical error.

A total of 43 locations[38] will be sampled within the beach areas (Map 3-5). The total number of locations within each beach area is roughly proportional to the size of the beach area. Beach areas of less than 3 ac are assigned three sampling locations (nine samples total), while larger beach areas are assigned more sampling locations. The number of locations contributing sediment to each beach area composite ranges from three to nine per beach, with the locations spatially balanced within each beach.

In future monitoring, the locations of the samples in the intertidal beach areas will be re-randomized to allow unbiased estimates of beach-specific conditions at each point in time. In addition, each individual sample from future monitoring events will be archived for 1 year to enable further investigation on a smaller spatial scale in the event that the post-remediation beach area results are higher than anticipated and exceed cleanup levels.

Sampling and Analytical Methods

The three composite samples per beach will be collected using the same sampling methods described for the clamming scenario, and they will be analyzed for the same analytes (Table 3-4). All of these samples will be from the 0–45-cm interval, to the extent possible.[39]

There are areas that are common to the beach play areas and the potential clamming areas. Therefore, 25 of the potential clamming area locations will also contribute to beach composite samples (Map 3-5). At these locations, sediment samples will be split; a portion of the sample will be composited in the potential clamming area composites and a portion of the sample will be composited in the beach play area composites. An additional 18 locations will be sampled for the beach play area composites to ensure that there are sufficient samples in the beach area composites.

[38] The 43 locations include 25 locations that are also potential clamming area locations and 18 locations that will only be sampled for the beach area composite samples.

[39] Rock, cobble, and other obstructions can prevent sampling to a depth of 45 cm.

3.2.1.5 Source-related sediment samples

In addition to the baseline sediment samples discussed in Sections 3.2.1.1 through 3.2.1.3, targeted source-related sediment sampling will be conducted under the third AOC amendment. These samples are intended to "help Ecology assess the sufficiency of contaminant source control through additional near-outfall sediment sampling and bank sampling" (EPA 2016).

Near-outfall Sediment Sampling

In 2014, Leidos conducted an assessment to identify sediment data gaps near outfalls, evaluate the feasibility of filling those gaps, and provide information needed to conduct additional outfall sediment sampling (Leidos 2014). Based on this assessment, Leidos recommended sediment sampling near outfalls that met the following criteria: 1) the outfall was active or presumed active, 2) it was not adjacent to a cleanup site, and 3) existing surface sediment data (i.e., two sediment samples collected within 50 to 100 ft from 2000 to present) were not sufficient. These outfalls are circled on Maps 3-6a through 3-6c.

To assist Ecology in its source evaluations, the outfalls recommended by Leidos (2014) for additional sediment sampling will be evaluated in the sediment QAPP based on the considerations presented in Figure 3-1. Based on this evaluation, additional source-related surface sediment samples will be collected if the criteria outlined in Figure 3-1 are met. The sediment QAPP will clearly present the results of the evaluation. Considerations regarding the need for additional sediment sampling include:

- Whether sufficient sediment data from the vicinity of the outfall exist[40]
- Whether the outfall can be sampled based on information presented in the Leidos (2014) assessment and consultation with Ecology, EPA, or Leidos

If appropriate based on consultation with the proper entity, a field reconnaissance will be conducted with Ecology to assess the sampleability of the sediments near the outfall prior to finalizing the QAPP. Visual information regarding riprap or other obstructions, such as piers, docks, and pilings, will be documented in the field notes and data report.

[40] Leidos evaluated data collected between 2000 and 2014. The QAPP evaluation will consider all available data in evaluating whether data exist within approximately 50 ft of Leidos-recommended outfalls with diameters of 24 in. or less, or within approximately 100 ft of outfalls with diameters of 24 in. or more.

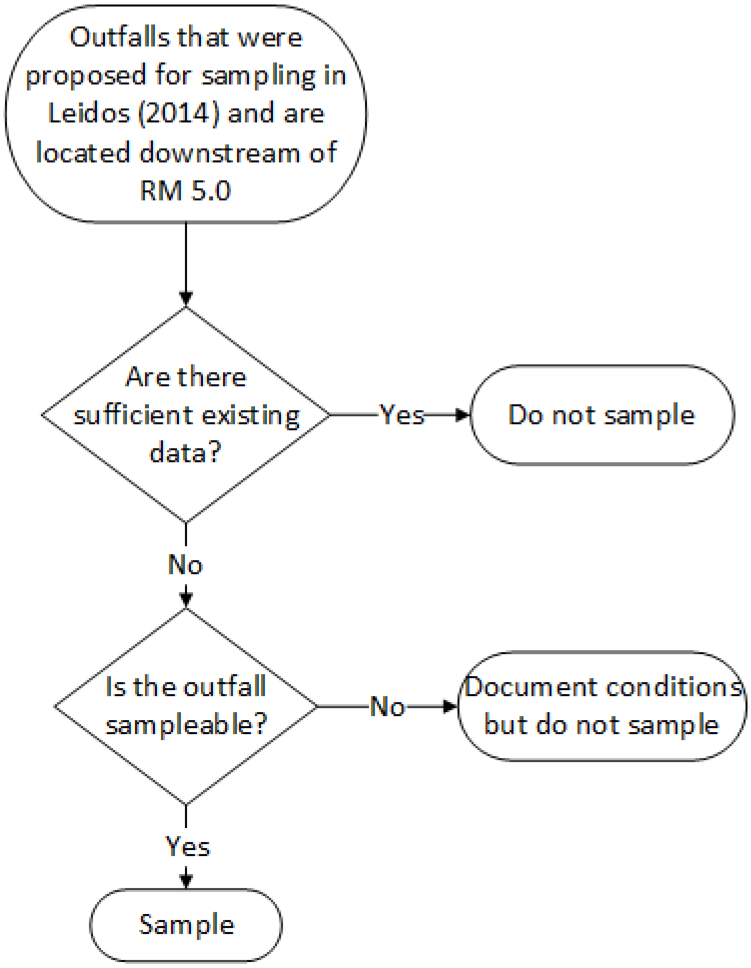

Figure 3-1.Selection criteria for sampling sediment near active outfalls

Sampling and Analysis Methods

If an outfall meets the above criteria for nearby sediment sampling, surface sediment sampling (0–10 cm) will be conducted following the methods discussed in Section 3.2.1.1. As part of the QAPP development, EPA and Ecology will be consulted regarding whether samples will be composited. Samples will be analyzed for the analytes listed in Table 3-3 (ROD Table 20 (EPA 2014)). Samples will also be analyzed for dioxins/furans, if the dioxin/furan toxic equivalent (TEQ) is greater than the remedial action level (RAL) in nearby sediment samples (i.e., samples collected near outfalls will be archived for potential dioxin/furan analysis pending the analysis of the sediment samples described in Sections 3.2.1.1 and 3.2.1.2). Additional details will be provided in the sediment QAPP.

Bank Soil Sampling

Uncharacterized exposed bank areas between +4 and +12 ft mean lower low water (MLLW)[41] may also be sampled to assist Ecology in source control.

In 2011, Hart Crowser sampled bank soils at nine areas on the LDW (Hart Crowser 2012). Eight of the nine areas were selected for sampling by Ecology to "assess the potential of sediment recontamination … because information about past use at the site or adjacent upland areas, or visual observations indicated that there may be suspect material on the bank that could be a source of sediment recontamination." One of the nine areas, the South Park Street end, which is easily accessible by the public, was sampled to confirm that bank soils at that location did not pose a risk to human health. These sampling data were imported to EIM.

In 2016, Leidos produced maps for Ecology delineating which exposed bank areas on the LDW have been characterized and which have not (LDWG 2016) (Map 3-7). This delineation was based on areas identified as exposed bank in the LDW FS (AECOM 2012) and the 2011 bank sampling locations.

To assist Ecology, uncharacterized exposed bank areas will be sampled as part of the pre-design studies if a bank meets the following criteria (Figure 3-2): 1) it is not adjacent to an upland cleanup site under or expected to be under an Agreed Order or an early action; 2) insufficient bank data exist; and 3) the bank can be sampled. The location of the bank area relative to preliminary dredge/cap areas (as identified in ROD Figure 18 (EPA 2014)) will also be considered, in consultation with EPA and Ecology, to determine if bank sampling in these areas may be more appropriately conducted during design.

Bank areas next to cleanup sites under or expected to be under an Agreed Order will not be sampled, because sampling should be done as part of the upland investigation, if needed. The remaining uncharacterized bank areas will be assessed[42] in a field reconnaissance survey to determine whether the locations can be sampled, based on substrate conditions, the presence and condition of overwater structures (which can create unsafe sampling conditions), and the presence of armoring. The method and criteria that will be used to assess whether a bank can be sampled will be provided in the sediment QAPP.

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[41] This elevation is approximately equal to mean higher high water (MHHW). NOAA reports MHHW at the Seattle station (Elliott Bay) as +11.36 ft MLLW (NOAA 2013).

[42] Access agreements will be needed in order to perform sampling on private property.

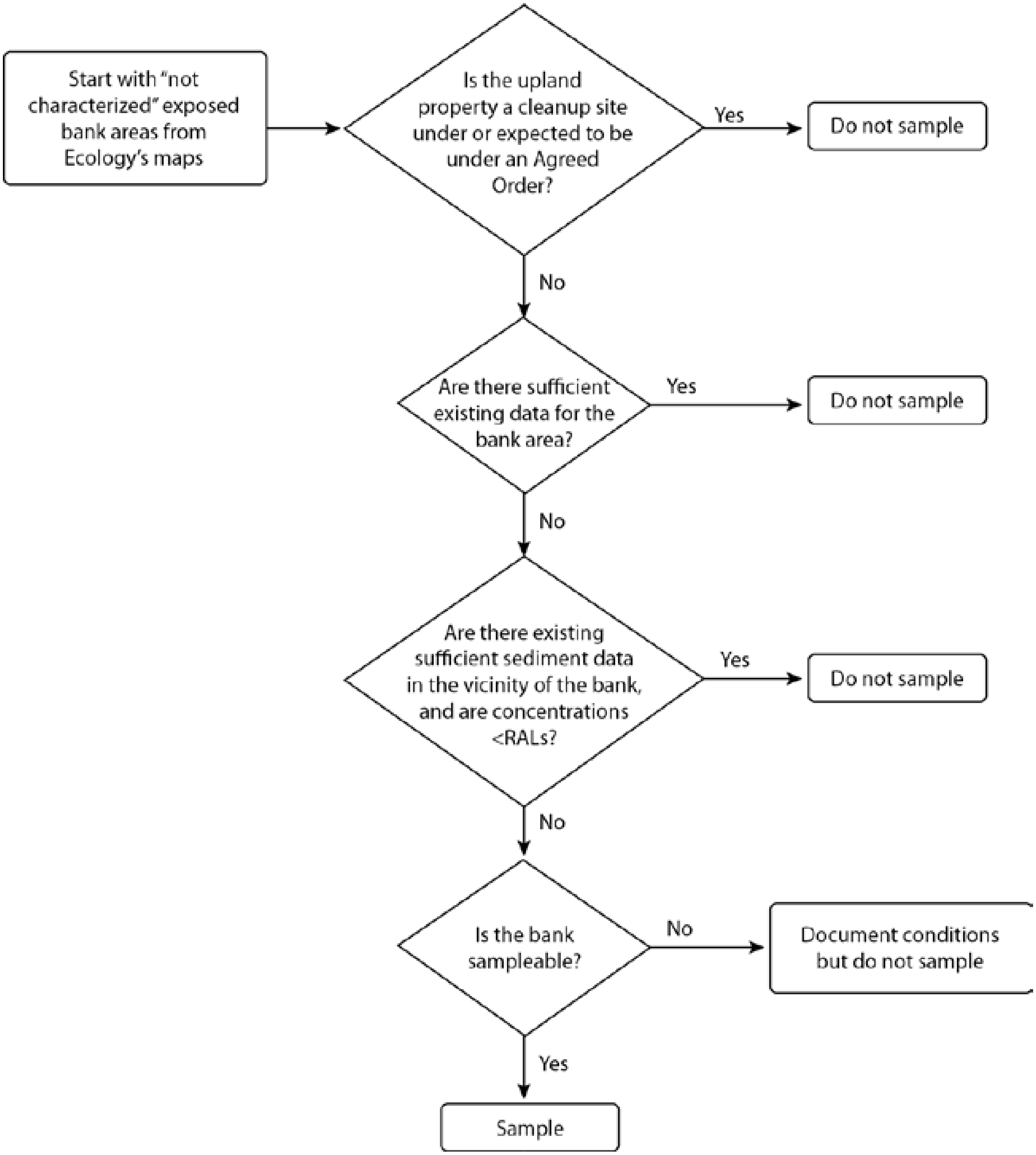

Figure 3-2.Selection criteria for sampling banks

Sampling and Analytical Methods

The reconnaissance survey methods will be identified in the sediment QAPP. The bank areas to be sampled and the number of samples to be collected at each location will be specified based on the survey and the other criteria outlined in Figure 3-2. Samples will be analyzed for the COCs listed in ROD Table 20 (EPA 2014) using the methods in Table 3-4 of this document. Samples will also be analyzed for dioxins/furans, if the dioxin/furan TEQ is greater than the RAL in nearby sediment samples (i.e., bank samples collected will be archived for potential dioxin/furan analysis pending the analysis of the sediment samples described in Sections 3.2.1.1 and 3.2.1.2). Bank samples will be collected by hand according to the methods outlined in Hart Crowser (2011). Additional details will be provided in the sediment QAPP.

3.2.2 Fish and crab tissue QAPP

The DQOs for the collection and analysis of LDW fish and crab tissue samples are as follows:

- To establish baseline site-wide 95UCL concentrations of risk drivers for comparison to target tissue levels (TTLs) for RAO 1
- To establish baseline site-wide mean concentrations to assess trends following sediment remediation for contaminants with TTLs[43]other

The fish and crab tissue sampling will also support risk communication related to human health consumption of resident seafood (RAO 1).

3.2.2.1 Study design and rationale

Based on the species sampled as part of the RI (Windward 2010a), the results of the fishers study (Windward 2016), and species with TTLs (ROD Table 21), three target species (English sole, shiner surfperch, and Dungeness crab) will be sampled from the LDW to establish baseline conditions.

English sole and Dungeness crab composite samples will be collected from two reaches of the LDW: Reach 1 (RM 0.0 to RM 2.9) and Reach 2 (RM 2.9 to RM 5.0) (Map 3-8). Reach 1 includes all areas where surveyed fishers reported fishing for resident species (Windward 2016). Reach 2 includes areas where surveyed fishers reported fishing for salmon only (Map 3-8). Individual fish and crab collected from within each reach will be composited, and the data across reaches will be combined to calculate 95UCL concentrations across the LDW for comparison to TTLs.

Shiner surfperch composite samples will be collected from four subreaches of the LDW,[44] each comprising one-fourth of the LDW: Reach 1a (RM 0.0 to RM 1.25), Reach 1b (RM 1.25 to RM 2.5), Reach 2a (RM 2.5 to RM 3.75), and Reach 2b (RM 3.75 to RM 5.0) (Map 3-9). Tissue data collected as part of the RI (Windward 2010a) indicated that PCB concentrations and congener patterns showed more spatial differentiation for

[43] As specified in ROD Table 21, titled *LDW resident fish and shellfish target tissue concentrations*, LDW resident fish and crab target tissue concentrations (EPA 2014).

[44] Each of these reaches includes one of the four areas sampled as part of the RI (Areas T1, T2, T3, and T4) (Windward 2010a). Reach 1a contains Area T1, Reach 1b contains Area T2, Reach 2a contains Area T3, and Reach 2b contains Area T4.

shiner surfperch than for other fish and crab species analyzed in the RI.[45] It is noted, however, that many factors influence contaminant concentrations in tissues, not just sediment exposures.

The optimal number of composite samples needed for each tissue type to achieve a RME of 25%[46] will be based on estimates of variability expected in the baseline composite tissue dataset using the RI tissue dataset (Appendix A). For each target species, the 95UCL for the site-wide mean will be estimated from multiple composite samples from each subreach or reach. Individuals will be collected within the targeted subreaches or reaches of the LDW, as described above, and multiple composite samples will be constructed for a given subreach or reach. Composite samples will be used to estimate the mean and variance of composite tissue concentrations within that subreach or reach, and results will be combined to estimate the site-wide mean and its 95UCL using stratified estimates. The stratified design will account for possible differences of mean and variability in composite tissue concentrations across subreaches and reaches.

Based on the analysis presented in Appendix A, a total of 12 samples will be created for English sole (whole body minus fillet; referred to as remainder[47]), English sole (fillet), Dungeness crab (edible meat), and Dungeness crab (whole body), with 6 samples collected in each of the 2 reaches shown in Map 3-8.

To reduce the variability observed in tissue composite samples during the RI sampling, each remainder and fillet English sole composite sample will include 10 fish. If sufficient English sole cannot be caught within a reach, starry flounder will serve as an alternate benthic fish. The authorization process to be followed for alternative species will be discussed in the tissue QAPP, along with compositing considerations.

Dungeness crab (edible meat) composite samples will include edible meat from five individuals, as was done in the RI. Hepatopancreas tissue samples (with equal contributions from 10 crabs each) will also be analyzed.[48] To calculate the

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[45] As stated in Windward (2010a), means of wet weight PCB concentrations in shiner surfperch were higher in Areas T2 and T3 and lower in Areas T1 and T4 in 2004, 2005, and 2007, and averaged over all years. Significant relationships between tissue and surface sediment were also identified on a subarea basis for shiner surfperch using 2004 data; PCB concentrations in surface sediment explained more than 50% of the variance in concentrations in tissue. Using 2005 data for shiner surfperch, the relationship was significant but less strong, explaining 29% of the variance. For English sole and Dungeness crab, regression relationships were not significant on an area basis using either 2004 or 2005 data, and PCB homolog patterns were consistent across the entire LDW.

[46] The analytical precision required by EPA functional guidelines for the analytical methods typically used in tissue characterization ranges from 20 to 50%.

[47] The English sole remainder and fillet data will be used to calculate whole-body concentrations.

[48] In each reach, 30 crabs (6 composite samples with 5 crabs each) will be collected to produce 6 edible meat composites and 3 hepatopancreas composites. Each hepatopancreas composite will contain hepatopancreas tissue from the 10 crabs represented in the corresponding 2 edible meat composites. Equal contributions from 10 crabs will be needed for each of the hepatopancreas samples to obtain sufficient mass for analysis.

concentrations in whole-body Dungeness crab for comparison to the TTLs (ROD Table 21 (EPA 2014)), the edible meat concentrations and the hepatopancreas concentrations will be mathematically combined based on the fraction of the whole body represented by each tissue type. Additional (i.e., more than five) individual crabs are not being added to each crab composite sample because it is difficult to collect sufficient numbers of crabs in the LDW.[49] If sufficient Dungeness crabs cannot be caught within a specific reach, slender crab will be considered as an alternate species, similar to the proposal above for English sole.

Based on the analysis presented in Appendix A of the 2007 shiner surfperch data, 3 composite samples per subreach (i.e., Reaches 1a, 1b, 2a, and 2b) for a total of 12 composite samples site wide are needed to achieve an RME of 25%. To reduce variability, each shiner surfperch composite sample will include 15 fish.

Long-term trends in tissue data may be evaluated using long-term monitoring data and parametric or non-parametric regression methods. In the short term, changes in tissue concentrations may be evaluated using a comparison of means between two time periods (e.g., a one-tailed, two-sample comparison, similar to a simple t-test but modified to be appropriate for the stratified sampling design and the distribution of the data). Power analyses,[50] described in Appendix A, indicate that the proposed sample design is expected to detect tissue concentration decreases equivalent to 30 to 75%[51] of the baseline means.

3.2.2.2 Sampling and analytical methods

Fish and crab will be collected using the trawling methods used in the RI (Windward 2010a). In addition, crab traps will be deployed as another method to collect Dungeness crabs. A trawling and collection plan addressing coverage of the subreaches or reaches outlined above is established in the tissue QAPP (Windward 2017a).

All Dungeness crab composite samples will be analyzed for human health seafood consumption COCs identified in ROD Table 14 (PCBs, inorganic arsenic, cPAHs, and dioxins/furans), using the methods listed in Table 3-5. PCB congeners will be analyzed

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[49] Dungeness crab catch per unit effort (CPUE) was low throughout the LDW in RI sampling events in 2004, 2005, and 2007. The target size range for Dungeness crabs is ≥ 9 cm total length, which is consistent with the target size range used in the LDW RI (Windward 2010a). Collecting crabs in this size range will maximize the likelihood of collecting sufficient numbers of crabs for chemical analyses; it will also consider the need to collect crabs large enough to be consumed by humans. Additionally, crabs in this size range are mostly adults that may have been exposed to LDW sediments for a longer period of time than juvenile crabs. Only male crabs will be retained.

[50] The power analyses presented in Appendix A calculate the minimum detectable difference (MDD) as the percent decrease from the baseline mean that is expected to be detected with 90% power and 95% confidence.

[51] The design is expected to detect decreases equivalent to the following percentages of baseline means: 40% (English sole fillet), 50% (English sole whole body), 35% (shiner surfperch), 30% (crab edible meat), and 30 to 75% (crab whole body, with and without outlier, respectively).

in a subset of the composites. The number of composites to be analyzed for each tissue type is listed in Table 3-5.[52] To serve as a baseline for long-term monitoring, a subset of samples (as noted in Table 3-5) will also be analyzed for the chemicals listed in ROD Table 14 and the appropriate chemicals listed in ROD Table 18.[53] In combination, these chemicals include selected SVOCs (bis[2-ethylhexyl] phthalate [BEHP], pentachlorophenol [PCP], carbazole, and hexachlorobenzene), tributyltin (TBT), vanadium, and organo-chlorine pesticides. A smaller subset of samples can be analyzed for these chemicals because they are not risk drivers.

Table 3-5. Summary of fish and crab tissue analytes, methods, RL goals, and numbers of tissue composite samples for each analyte

Analyte	Method	RL Goal	TTL (ROD Table 21)	No. of Composite Samples of Each Tissue Type		
				English Sole	Crab[a]	Shiner Surfperch
Total PCBs (µg/kg ww)	EPA 8082A (Aroclors)	4[b]	12 (benthic fish, fillet) 1.8 (pelagic fish, whole body) 1.1 (crab, edible meat) 9.1 (crab, whole body)	12[c] (6 per reach)	12[d] (6 per reach)	12[e] (3 per subreach[f])
PCB congeners (sum) (µg/kg ww)	EPA 1668C	0.0004	12 (benthic fish, fillet) 1.8 (pelagic fish, whole body) 1.1 (crab, edible meat) 9.1 (crab, whole body)	6[g] (3 per reach)	8[g] (4 per reach)	8[g] (2 per subreach)
Inorganic arsenic (mg/kg ww)	EPA 1632	0.010	na	12 (6 per reach)	12 (6 per reach)	12 (3 per subreach)
cPAH (µg TEQ/kg ww)	EPA 8270D-SIM	4.5[h]	na	na	12 (6 per reach)	na
Dioxins/furans (ng TEQ/kg ww)	EPA 1613B	1.14[i]	0.35 (benthic fish, whole body) 0.53 (crab, edible meat) 2.0 (crab, whole body)	12 (6 per reach)	12 (6 per reach)	12 (3 per subreach)

[52] In addition to the subsets of tissue samples to be analyzed for PCB congeners, if none of the PCB Aroclors are detected in a sample, then the sample will be submitted for analysis of PCB congeners. The combination of these methods will ensure that the PCB concentrations are sufficiently sensitive relative to the PCB TTL.

[53] COPCs listed in ROD Table 18, titled *Rationale for selection of contaminants as COCs for ecological risk*, for spotted sandpiper will not be analyzed in fish and crab because only benthic invertebrate tissue and sediment analyses are relevant. Also, the benthic invertebrate COPCs listed in ROD Table 18 will not be analyzed in fish and crab tissue because these COPCs are only applicable in sediment analyses (EPA 2014); likewise cadmium, which was assessed using a dietary approach, will not be analyzed in fish tissue.

Analyte	Method	RL Goal	TTL (ROD Table 21)	No. of Composite Samples of Each Tissue Type		
				English Sole	Crab[a]	Shiner Surfperch
BEHP (µg/kg ww)	EPA 8270D	50.0	na	2 (1 per reach)	2 (1 per reach)	2 (1 per reach[f])
PCP (µg/kg ww)	EPA 8270D	100	na			
TBT (µg/kg ww)	EPA 8270D-SIM	3.86	na			
Vanadium (mg/kg ww)	EPA 6020A	0.004	na			
Aldrin (µg/kg ww)	EPA 8270D/ 1699 Mod	1.0	na			
alpha-BHC (µg/kg ww)	EPA 8270D/ 1699 Mod	1.0	na			
beta-BHC (µg/kg ww)	EPA 8270D/ 1699 Mod	1.0	na			
Carbazole (µg/kg ww)	EPA 8270D	20.0	na			
Total chlordane (µg/kg ww)	EPA 8270D/ 1699 Mod	2.0	na			
Total DDTs (µg/kg ww)	EPA 8270D/ 1699 Mod	2.5	na			
Dieldrin (µg/kg ww)	EPA 8270D/ 1699 Mod	1.0	na			
gamma-BHC (µg/kg ww)	EPA 8270D/ 1699 Mod	1.0	na			
Heptachlor (µg/kg ww)	EPA 8270D/ 1699 Mod	1.0	na			
Heptachlor epoxide (µg/kg ww)	EPA 8270D/ 1699 Mod	1.0	na			
Hexachlorobenzene (µg/kg ww)	EPA 8270D	20.0	na			

Note: All tissue samples will be analyzed for lipids and total solids. The number of individual specimens comprising each composite sample will be: 5 (Dungeness crab edible meat), 10 (Dungeness crab hepatopancreas, English sole fillet, and English sole whole body), and 15 (shiner surfperch whole body).

a Numbers of composite samples are for crab edible meat. The number of hepatopancreas composite samples to be analyzed per analyte is one-half of the number of edible meat composite samples.

b If none of the PCB Aroclors are detected in a sample, then the sample will be submitted for analysis of PCB congeners by Method 1668C with an estimated RL of 0.0004 µg/kg.

c For English sole,6 fillet and 6 remainder samples will be analyzed in each reach for a total of 12 English sole tissue samples in each reach.

d For Dungeness crab, 6 crab edible meat samples and 3 hepatopancreas samples will be analyzed in each reach.

e Only whole-body samples of shiner surfperch will be analyzed.

f Shiner surfperch from each subarea within a reach will be combined into a single composite sample for these analytes (e.g., shiner surfperch from subreaches 1a and 1b will be combined into a Reach 1 composite sample).

g The samples analyzed for PCB congeners represent a minimum of 50% of the composite samples. All of these samples will be analyzed for PCB Aroclors.

h The RL cPAH TEQ value was calculated using one-half the RL for each of the cPAH compounds and appropriate TEF values (California EPA 2009).

i The dioxin/furan RL is based on the laboratory minimum calibration level from Axys; the dioxin/furan mammalian TEQ value was calculated using one-half the RL for each dioxin/furan compound and appropriate mammal TEF values (Van den Berg et al. 2006).

Axys – Axys Analytical Services, Ltd.
BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
EPA – US Environmental Protection Agency
na – not available
PCB – polychlorinated biphenyl
PCP – pentachlorophenol
RL – reporting limit
ROD – Record of Decision
SIM – selected ion monitoring
TBT – tributyltin
TEF – toxic equivalency factor
TEQ – toxic equivalent
TTL – target tissue level
ww – wet weight

Lipids and total solids will also be analyzed in each tissue composite sample. The analytical methods and RLs for the conventional parameters are provided in Appendix B.

All fish composite samples will be analyzed for the same analytes as described above for Dungeness crab, with the exception of cPAHs, which will not be analyzed in fish tissue because they are metabolized (Collier et al. 2013).

In future monitoring events, the target numbers of composite samples may change from the baseline design as a result of updated estimates of mean and variance. The analyte list may change as well.

3.2.3 Clam tissue QAPP

The DQOs for the collection and analysis of LDW clam tissue samples are as follows:

- To establish baseline site-wide 95UCL concentrations of risk drivers for comparison to TTLs for RAO 1
- To calculate baseline site-wide mean clam tissue concentrations to assess trends following sediment remediation for contaminants with TTLs[54]

The clam tissue sampling will also support risk communication related to human health consumption of resident seafood (RAO 1).

3.2.3.1 Study design and rationale

The RI had 12 clam collection areas (Windward 2010a), including two areas in Slip 4; for this study, the two areas in Slip 4 (which has been remediated) will be combined into a single area for a total of 11 clam collection areas. One clam composite sample will be collected from each of the 11 clam collection areas (Map 3-10) where clams are available.[55] Each composite sample will contain 20 to 25 *Mya arenaria* clams collected from each area. The data from all of the clam composite samples will be combined to calculate the site-wide 95UCL for the LDW, as specified in ROD Table 21 (EPA 2014) (see Appendix A for details).

[54] As specified in ROD Table 21, LDW clam target tissue concentrations (EPA 2014)).

[55] Because the areas in Slip 4 and Terminal 117 were remediated in early actions, clams may not be available, in which case no tissue samples would be collected from these areas.

3.2.3.2 Analytical and sampling methods

Clams will be collected by hand using shovels in the same manner as described in the benthic invertebrate QAPP for the RI (Windward 2004b). In brief, clams (*M. arenaria*) will be collected for chemical analyses at low tide following the CPUE method used in 2003 during the clam abundance survey. This method will involve field crew members actively searching for and collecting clams from areas within the intertidal clam tissue collection areas (Map 3-10) with the highest clam abundance, as determined by evidence of shows. At each intertidal area, a total of one composite tissue sample consisting of at least 81 g of clam tissue (excluding shells) will be collected. This composite sample will consist of at least 20 to 25 clams.

Clam composite samples will be analyzed for human health seafood consumption COCs (PCBs, dioxins/furans, cPAHs, and inorganic arsenic) identified in ROD Table 14 (EPA 2014) (Table 3-6). Lipids and total solids will also be analyzed in each composite sample, and PCB congeners will be analyzed in six[56] composite samples in order to calculate PCB TEQs.

Table 3-6. Summary of clam tissue analytes, analytical methods, RL goals and numbers of samples

Analyte	Method	RL Goal	TTL (ROD Table 21)	No. of Composite Samples
Inorganic arsenic (mg/kg ww)	EPA 1632	0.01	0.09	11 main body without siphon skin; 11 siphon skin
Vanadium (mg/kg ww)	EPA 6020A	0.004	na	3
cPAH (µg TEQ/kg ww)	EPA 8270D-SIM	0.025–2.5[a]	0.24	11
Dioxins/furans (ng TEQ/kg ww)	EPA 1613B	0.0000075–0.025[b]	0.71	11
Total PCBs (µg/kg ww)	EPA 8082A (Aroclors)	4[c]	0.42	11
PCB congeners (sum) (µg/kg ww)	EPA 1668C	0.0001	0.42	6
BEHP (µg/kg ww)	EPA 8270D	50.0	na	3
Carbazole (µg/kg ww)	EPA 8270D	20.0	na	3
PCP (µg/kg ww)	EPA 8270D	100	na	3
TBT (µg/kg ww)	EPA 8270D-SIM	3.86	na	3
Aldrin (µg/kg ww)	EPA 8270D/1699 Mod	1.0	na	3
alpha-BHC (µg/kg ww)	EPA 8270D/1699 Mod	1.0	na	3
beta-BHC (µg/kg ww)	EPA 8270D/1699 Mod	1.0	na	3

[56] In addition to the six clam tissue composites to be analyzed for PCB congeners, if none of the PCB Aroclors are detected in a sample, then the sample will be submitted for analysis of PCB congeners. The combination of these methods will ensure that the PCB concentrations are sufficiently sensitive relative to the PCB TTL.

Analyte	Method	RL Goal	TTL (ROD Table 21)	No. of Composite Samples
Total chlordane (µg/kg ww)	EPA 8270D/1699 Mod	2.0	na	3
Total DDTs (µg/kg ww)	EPA 8270D/1699 Mod	2.5	na	3
Dieldrin (µg/kg ww)	EPA 8270D/1699 Mod	1.0	na	3
gamma-BHC (µg/kg ww)	EPA 8270D/1699 Mod	1.0	na	3
Heptachlor (µg/kg ww)	EPA 8270D/1699 Mod	1.0	na	3
Heptachlor epoxide (µg/kg ww)	EPA 8270D/1699 Mod	1.0	na	3
Hexachlorobenzene (µg/kg ww)	EPA 8270D	20.0	na	3

Note: All tissue samples will be analyzed for lipids and total solids.

[a] cPAH TEQ-based RL values for individual cPAH compounds were calculated using RLs and the appropriate TEF values (California EPA 2009). The values for all cPAH compounds are provided in Appendix B.

[b] Dioxin/furan TEQ-based RL values for individual dioxin/furan congeners were calculated using RLs and appropriate mammal TEF values (Van den Berg et al. 2006). The DLs for all dioxin/furan congeners are provided in Appendix B.

[c] If none of the PCB Aroclors are detected in a sample, then the sample will be submitted for analysis of PCB congeners by Method 1668C with an EDL of 0.0001 µg/kg. This estimated EDL is based on the laboratory-estimated DL from Axys and represents the value for an individual PCB congener. Individual congener EDLs are listed in Appendix B. The reported EDLs will vary based on the sample mass and the analytical conditions at the time of analysis.

BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
DL – detection limit
EDL – estimated detection limit
EPA – US Environmental Protection Agency
na – not available
PCB – polychlorinated biphenyl
PCP – pentachlorophenol
RL – reporting limit
ROD – Record of Decision
SIM – selected ion monitoring
TBT – tributyltin
TEF – toxic equivalency factor
TEQ – toxic equivalent
TTL – target tissue level
ww – wet weight

In addition to the four human health COCs, to serve as a baseline for long-term monitoring, three clam composite samples will be analyzed for the other chemicals listed in ROD Table 14 (EPA 2014). These chemicals include BEHP, PCP, TBT, vanadium, and organo-chlorine pesticides (Table 3-6). The three clam composite samples analyzed for the COPCs will contain equal portions of tissue from the composite samples from each of the following intertidal segments: RM 0 to RM 1.3 (i.e., clamming areas 1 to 3), RM 1.3 to RM 2.6 (i.e., clamming areas 4 to 6), and RM 2.6 to RM 3.9 (i.e., clamming areas 7 to 11) (Map 3-10). Details regarding the compositing strategy will be presented in the clam tissue QAPP.

The Oregon Department of Environmental Quality (ODEQ) (Oregon DEQ 2015) and RARE clam and arsenic study (Kerns et al. 2017) have reported that *M. arenaria* accumulate a larger fraction of both total and inorganic arsenic in their siphon skin (relative to the rest of the body). Because of this, inorganic arsenic will be analyzed in both siphon skin and the remaining edible clam meat in all of the clam composite samples in the baseline sampling. These data are meaningful from a health advisory perspective as well as to further track if clam tissue minus the siphon skin is progressing toward the inorganic arsenic TTLs. ODEQ's health advisory states: "the inorganic arsenic found in softshell clams can be greatly reduced by removing the siphon skin before eating, and therefore it is recommended that the siphon skin be removed before consuming."

Based on a recent investigation (Appendix F), the data indicate that cPAHs are not preferentially accumulating in siphon skin relative to the remainder of clam tissue. Therefore, analysis of clam tissues for cPAHs will be performed on composites of whole-body clam tissue that include siphon skin tissue.

3.2.4 Surface water QAPP

The DQOs for the collection and analysis of LDW surface water samples are as follows:

- To assess progress toward water quality applicable or relevant and appropriate requirements (ARARs) as sediment remediation and source control continue
- To establish baseline concentrations to be used to assess trends in PCB concentrations in surface water as sediment remediation and source control continue

3.2.4.1 Study design and rationale

As described in the CSM (Section 1.1.3), it is important to consider how the LDW functions as a tidal estuary with upstream dam control when designing the water sampling program to establish baseline conditions and long-term monitoring.

As is typical of a tidally influenced estuary, a well-defined salt wedge is present in the LDW that can extend from RM 1.8 to beyond RM 5.0, depending on upstream flow and tidal conditions. Also, flow rates in the LDW are variable and can influence water quality. The flow rates are influenced by three main factors: tidal cycles (and their relative magnitude), recent precipitation, and water release rates from the Howard Hanson Dam. These factors intersect to result in a range of river conditions.

The following key factors were considered in the study design, which is presented separately for each DQO:

- Salt wedge and freshwater and saltwater layers within water column
- Different flow rates, storm conditions, and dam releases typically seen in the system
- Tidal cycles

Composite-grab Samples

Spatial Distribution

For spatial coverage, surface water samples will be collected at two locations in the LDW (RM 0.75 and RM 3.3) and one upstream reference location. The upstream reference location will be at RM 10 of the Green River, at the Foster Links Golf course.[57] Because the LDW is a dynamic estuarine system, localized impacts of sediment cleanup activities are not expected to be discernable in the water column. Thus, information related to sediment cleanup is not considered in the selection of sampling locations. Because the available information (as described in Sections 2.2 and 2.3) suggests that surface water is well mixed laterally across the LDW, samples will be collected only in the central portion of the waterway.

Water Column Layers

To evaluate potential differences in concentration between the freshwater (i.e., near-surface) layer and the marine saltwater (i.e., near-bottom) layer of the LDW, each of the two LDW sampling locations will be sampled at two water depths. A near-surface water sample will be collected 1 m below the surface of the water, and a near-bottom water sample will be collected 1 m above the sediment surface (generally representing the marine saltwater layer).[58] A vertical profile of salinity data (and other relevant water quality information) will be recorded during sample collection. The upstream location will be sampled at the midpoint of the water column; near-surface and near-bottom samples will not be needed because of the absence of the marine saltwater layer in this portion of the river and the relatively shallow river depth.

Flow Conditions

The composite-grab sampling events will represent a range of flow conditions in order to characterize chemical concentrations in LDW surface water under a variety of flow conditions. As described in the CSM (Section 2), the targeted flow conditions are anticipated to include the conditions that result in the highest concentrations of chemicals such as PCBs. The following definitions will be used:

- **Storm event** – Precipitation forecasted to be greater than 0.25 in. within a 24-hour period (Storms 1 and 3, Table 3-7) and greater than 0.50 in. within a 24-hour period (Storms 2 and 4, Table 3-7).

[57] This Green River location was selected for consistency with past sampling conducted by USGS and King County.

[58] Samples will be collected regardless of the salinity at the time of sampling. For example, the near-bottom sample may or may not represent the marine layer depending on the location of the salt wedge at the time of sampling.

- **Significant dam release**[59] – A flow rate greater than 2,000 cfs at the USGS gage just below the Howard Hanson Dam (Gage 12105900), which represents the rate of release from the dam.
- **Baseflow** – Average flow rates within wet and dry seasons, measured as rates of discharge at the USGS gage just below the Howard Hanson Dam (i.e., daily averages of approximately 200–600 cfs during the dry summer months and approximately 800–1,200 cfs during the wet winter months).

To assess concentrations within this dynamic system, four sampling efforts will be conducted to target storm events (two with and two without a significant dam release), two sampling events will be conducted to target dry baseflow conditions, and two sampling events will be conducted to target wet baseflow conditions (Table 3-7). These eight sampling events are anticipated to bracket the range of varying conditions in the LDW. Information regarding flow conditions and precipitation will be presented along with the sampling results for each sampling event in the data report.

Table 3-7. Composite-grab sampling events

Sampling Event	Targeted Precipitation[a]	Targeted Dam Release Conditions[b]	Target Schedule
Dry baseflow 1[c]	3-day antecedent period without measurable rainfall	targeting dry season average dam releases (e.g., 200–600 cfs)	August/ September 2017
Storm 1[d]	> 0.25 in. in 24-hour period with 48-hour antecedent period without heavy rainfall[e]	no significant dam release (< 2,000 cfs)	September/ October 2017[f]
Storm 2[d]	> 0.5 in. in 24-hour period with 48-hour antecedent period without heavy rainfall[e]		
Storm 3[d]	> 0.25 in. in 24-hour period	with significant dam release (> 2,000 cfs)	Nov. 2017 to Jan. 2018
Storm 4[d]	> 0.5 in. in 24-hour period		
Wet baseflow 1[c]	3-day antecedent period without measurable rainfall	targeting wet season average dam releases (e.g., 800–1,200 cfs)	Dec. 2017 to March 2018
Wet baseflow 2[c]			
Dry baseflow 2[c]	3-day antecedent period without measurable rainfall	targeting dry season average dam releases (e.g., 200–600 cfs)	July/August 2018

a Forecasted precipitation will be based on local rainfall projections from the NOAA weather website. Rainfall prior to sampling (i.e., the antecedent period) will be based on measurements taken at the Hamm Creek gage (HAU2). Details will be provided in the surface water QAPP.

b Dam releases are as measured at the USGS gage just below the Howard Hanson Dam (Gage 12105900). Details will be provided in the surface water QAPP.

c If possible, dry and wet baseflow sampling will target spring and neap tides (i.e., one dry and one wet baseflow event will be conducted during spring tides, while the other dry and wet baseflow events will be conducted during

59 Significant dam releases are not defined by USACE. Rather, a significant dam release was defined as a rate greater than 2,000 cfs for consistency with rates used by King County and USGS water sampling programs (King County 2014; USGS 2016, 2017).

neap tides). A spring tide (which occurs just after a new or full moon) is when there is the largest difference between high and low tides, while a neap tide (which occurs halfway between a new and full moon) is when there is the smallest difference between high and low tides.

[d] Samples will be generally collected within 12 hours of the period during a storm that is predicted to have a greater amount of rainfall. Details are provided in the surface water QAPP (Windward 2017b).

[e] During the antecedent 48-hour period, up to approximately 0.2 in. of precipitation will be considered acceptable.

[f] If storm event samples without significant dam release cannot be collected in 2017, attempts will be made in September/October 2018.

cfs – cubic feet per second
EPA – US Environmental Protection Agency
LDWG – Lower Duwamish Waterway Group
NOAA – National Oceanic and Atmospheric Administration
QAPP – quality assurance project plan
USGS – US Geological Survey

Tidal Cycles and Sample Timing

Each composite-grab sample will be a composite of four grab samples collected at least 1 hour apart. This compositing approach will integrate short-term temporal variability to provide a better basis for the evaluation of trends in long-term monitoring.

For dry and wet baseflow sampling events, sampling will be conducted during a consistent portion of the tidal cycle to increase the comparability of these events for long-term monitoring. Thus, for the LDW locations, the sampling period will be approximately centered around a daytime high tide to maximize the residence time of the near-bottom layer and the likelihood of sampling the marine layer at the upper LDW location. The upstream reference location will be sampled during outgoing tide to ensure that all flow is from the Green River Watershed during sampling. Details of the tidal cycle will be recorded during each sampling event.

For storm events, because of the need to target certain precipitation levels and dam release conditions, specific tidal cycles will not be targeted. Tidal conditions at the time of sampling will be documented.

Passive Samplers

This section provides an overview of the sampling design for the passive samplers. In order to provide a baseline dataset for PCBs that can be used to assess long-term trends, it is important to control for as many variables as possible. Thus, the CSM for the LDW was used to reduce the large number of sampling targets (e.g., location, depth, and season) to a reasonable subset that could be measured effectively during baseline sampling, and from which temporal inference could be made. The sampling design for the passive samplers and its rationale are summarized in Table 3-8 (additional details are provided in the surface water QAPP (Windward 2017b)).

Table 3-8. Summary of passive sampler conceptual design and rationale

Design Component	Approach	Rationale
Passive sampler material	PE	PE is the recommended material to be used during passive sampler water column deployments for PCBs, as it allows for sufficient polymer mass to ensure reliable detection (EPA et al. 2017). The passive sampler consists of steel mesh envelopes containing PE strips that are suspended from a frame in the water column.
Deployment duration	1 month	The most chlorinated PCB congeners can take several months to 1 year to fully equilibrate using a PE passive sampler (Tcaciuc et al. 2015). PRCs will therefore be used to correct for non-equilibrium conditions. One month is recommended as a balance between achieving sufficient equilibration within the sampler (to allow for reliable equilibrium corrections using PRC data), and minimizing the potential for sampler loss or biofouling. The 1-month period also integrates and averages the actual short-term variability of PCB concentrations in the water, resulting in a measurement that allows for a more powerful assessment of long-term trends (Windward and Integral 2017a; Appendix A).
Location	2 locations (RM 2.0 and RM 3.3 - South Park Bridge)	These locations have the permanence required to deploy a sampler so that it is less likely to be lost due to vessel traffic. The upstream location provides consistency with the composite grab sample location (RM 3.3), where the near-bottom water is generally within the marine layer during the dry season.[a] The downstream location provides a second location to afford more data within the LDW.
Season	dry baseflow - summer (August)	Based on existing whole-water data and the CSM presented in this work plan, the highest PCB concentrations are expected in the near-bottom water layer during the lower water flows encountered in the dry season. Within-season variability will be minimized by using month-long deployment.
Depth	1 m above sediment	The influence of the sediment remedy is of interest, and therefore the near-bottom layer of water was selected so that the passive sampler more directly represents the water influenced by PCBs flux from sediments than from other sources. This depth also ensures consistent exposure to the water column (i.e., tidal changes make higher elevation deployment more of a concern). Finally, this depth is consistent with the lower collection depth of the composite-grab samples being collected for DQO 1 (see Section 4.1.1.2).
Frequency	samplers deployed in August 2017 and August 2018	Samples will be collected over 2 years to assess 2 dry baseflow periods.
Number of replicates	9 replicates at each location (attached to separate supports)	Nine replicate samplers will be deployed at the same location and during the same sampling event in order to capture the variability of passive sampler analysis (see power analysis [Appendix A]). Six additional samplers (for a total of 15) will be deployed in case any samplers are lost.

[a] The water in the near-bottom layer has longer residence time during low flows, because there is less entrainment into the outflowing surface layer, which reduces the net inflow from Elliott Bay.

CSM – conceptual site model
DQO – data quality objective
LDW – Lower Duwamish Waterway
PCB – polychlorinated biphenyl
PE – polyethylene
PRC – performance reference compound
RM – river mile

3.2.4.2 Analytical and sampling methods

Composite-grab Samples

Composite-grab sampling for the two LDW locations will be conducted from a boat. As described, one composite sample representing the near-surface layer and one composite sample representing the near-bottom layer will be collected at each LDW location. The upstream reference location sampling will be conducted from a bridge; the sample at this location will be collected from the midpoint of the water column.

When collecting each grab sample, conventional water quality parameters will be measured throughout the water column at each location using a multi-meter probe. Water quality parameters will be measured using a multi-parameter water quality meter to record a profile of the entire water column for conductivity, temperature, dissolved oxygen, pH, and turbidity.

Each grab sample will be collected using a Niskin bottle sampler, which will be lowered to the target depth on a line and triggered to close. Four grab samples will be collected at both sampling depths (i.e., near-surface and near-bottom water for the LDW locations) and composited into one sample per depth at each location. Details on the sampling method are provided in the surface water QAPP (Windward 2017b).

The composite-grab samples will be analyzed for analytes included in Washington's water quality standards (Washington Administrative Code [WAC] 173-201A-240), the Washington Toxics Rule (40 Code of Federal Regulations [CFR] 131.45 as applied to Washington[60]), and national recommended ambient water quality criteria (AWQC),[61] with a few exceptions. The ARAR is the most stringent of the water quality criteria (WQC) from Washington Administrative Code 173-201A, NTR (40 CFR 131.45 as applied to Washington), and AWQC values. Volatile organic compounds (VOCs) will not be analyzed in the water samples because these compounds are volatile, rarely detected in surface water samples, and cannot be analyzed in a composite water sample. In addition, VOCs are not LDW COCs or COPCs for human health.

In addition, two organophosphorus pesticides (Demeton and Guthion) and two herbicides (2,4,5-TP and 2,4-D) that have water quality standards will not be analyzed in water samples because they are agricultural compounds that are rarely detected at concentrations above AWQC in water quality monitoring in agricultural areas (Tuttle et al. 2017). None of these analytes were detected in samples collected from the LDW at its confluence with the Black River by King County in 1996. These compounds are not COCs, and there is no indication of a source of these compounds at industrial uses along the LDW; they are generally restricted in use to specific agriculture applications. These pesticides and herbicides are not persistent in the environment, with half-lives on

[60] Washington State criteria include standards promulgated in WAC 173-201A and human health criteria consistent with the Washington Toxics Rule (40 CFR 131.45, as applied to Washington) and 40 CFR 131.36 (d)(14), including the 40 CFR 131 criteria updated on November 28, 2016. These criteria were updated after publication of the ROD.

[61] For the LDW, the relevant and appropriate AWQC for the protection of human health are only those established for the consumption of organisms, because LDW surface water is not a source of potable water, and for those analytes that could come from sediments or lateral sources entering the site. The relevant and appropriate AWQC for the protection of aquatic life are the aquatic marine criteria.

the order of weeks to months (USDA 2016). Guthion and 2,4,5-TP have been banned from use in the United States since 2013 and 1985, respectively.

The specific analytes, analytical methods, and RL goals are provided in Table B-6 of Appendix B. All of the RL goals for metals, except thallium, are below the corresponding WQC. The RL goals for TBT, some SVOCs, and pesticides are higher than the lowest WQC for these compounds. The analytes for which the RL goals are above the lowest criteria value are highlighted in Appendix B. The selected analytical methods are the most sensitive methods available for these analytes.

After the completion of sampling events in 2017 (i.e., the first three sampling events, including the first dry baseflow event and the first two storm events [without significant dam release], as outlined in Table 3-7), the analyte list will be evaluated based on data from these two events, as well as historical water data from the LDW and East Waterway (Windward and Anchor QEA 2014; Windward 2010a). If analytes are not detected or are well below WQC, LDWG will prepare a memorandum for EPA approval indicating which analytes will be deleted from the analyte list for the remaining baseline sampling events and future monitoring.[62] Future monitoring events, to be conducted as part of the long-term monitoring program, may also have fewer sampling locations and depths intervals, depending on the results and objectives of the program.

Passive Samplers

Passive samplers will consist of a stainless steel mesh envelope containing a low-density PE strip attached to a polyvinyl chloride (PVC) frame. The PE strips will be 25 µm thick and cut into 5- × 6-in. strips. The stainless steel mesh envelope will protect the PE strips from loss and damage, and will be customized to fit the PE strips. Passive samplers will be prepared for deployment using methods based on those outlined by (Gschwend et al. 2012).

Passive samplers will be attached to the PVC sampling frame in groups of five for deployment; three sampling frames will be deployed at each location for a total of 15 passive samplers at each location. The deployment frames will be used as the primary structure to suspend the passive samplers in the near-bottom layer of the water column. Anchor weights will be attached across the bottom of the frame to secure the samplers and minimize the agitation of nearby sediment. The loaded frames will then be deployed from a boat by lowering the frames to the sediment surface; they will be secured to the structure's fender boards or pilings when the anchor weights reach the bottom. A multi-parameter data logger will be deployed at the same depth as the passive samplers at each location. The data logger will collect *in situ* water quality data

[62] Organophosphate and carbamate pesticides will be analyzed only in the surface water samples collected during the first storm event.

(e.g., conductivity, temperature, dissolved oxygen, and pH) for the duration of the sampling period.

After approximately 30 days, the passive sampler frames will be retrieved from the site. The PE strips will be extracted and analyzed for PCB congeners. As described in the surface water QAPP, the lowest possible detection limits (DLs) for PCB congeners in surface water based on the results from the PE passive samplers will be calculated based on the laboratory analytical DLs for the PE strips, the partition coefficients between surface water and PE (from Gschwend et al. 2014), and equilibrium assumptions.

3.2.5 Seep QAPP

Seep samples will be collected as part of the pre-design studies to aid Ecology in source identification. Seep sampling will be conducted to determine if groundwater may be a significant ongoing source of contamination in areas where existing groundwater data are insufficient.

Most of the significant seeps in the LDW have been sampled as part of the RI or other programs (Windward 2004a, 2010a). Based on this information, available groundwater information, and a reconnaissance survey, any seep sampling locations will be determined based on the criteria outlined in the flow chart depicted in Figure 3-3.

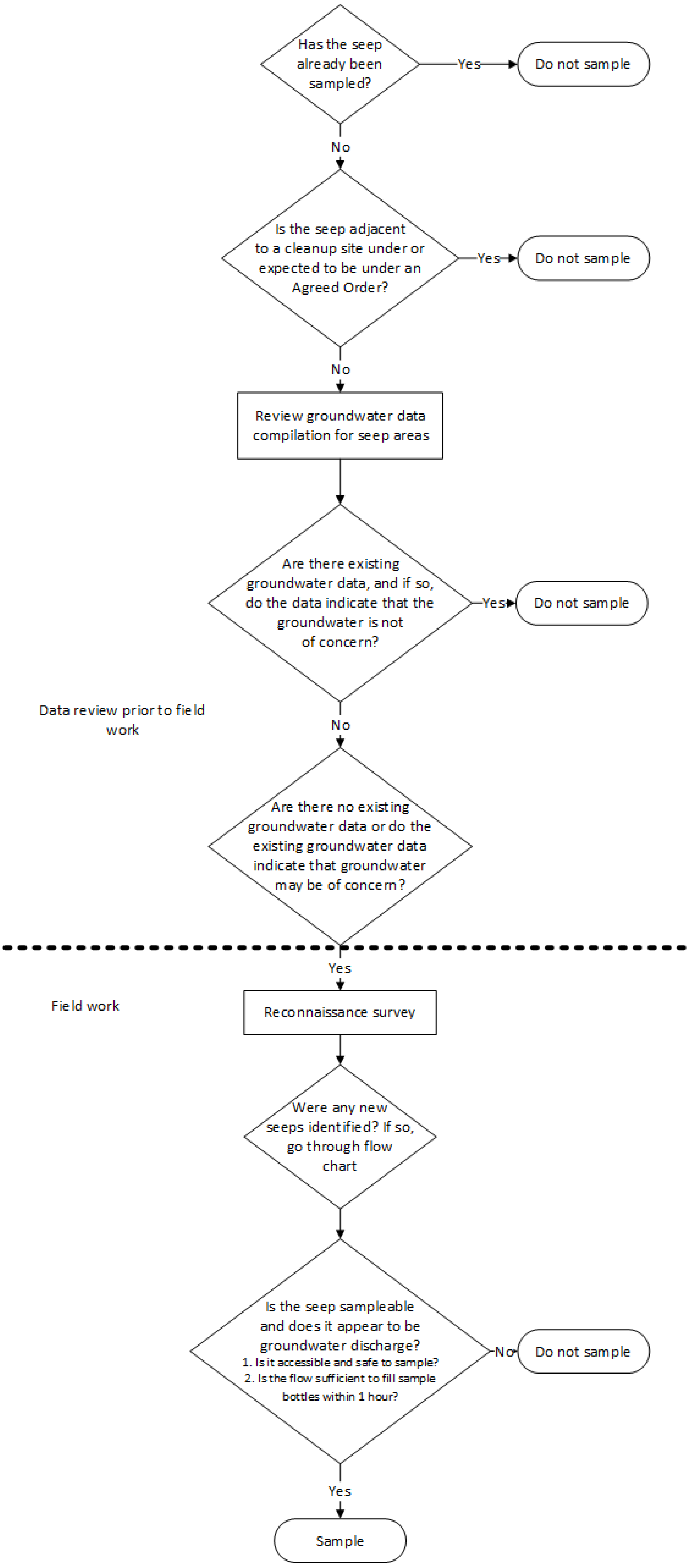

Figure 3-3.Selection criteria to determine if seeps should be sampled

In the seep QAPP, existing data will be reviewed to identify the locations of known seeps, seeps that have been sampled previously, and sites under or expected to be under an Agreed Order. In addition, groundwater data will be reviewed to determine if nearby groundwater data exist, and if so, whether the groundwater data indicates a potential source of recontamination to the LDW. The results of these evaluations will be clearly presented in the seep QAPP.

During the reconnaissance survey (to be conducted several weeks before seep sampling), the field team will look for evidence of flow with sufficient volume to sample. The GPS location of each seep will be recorded and a stake will be used to mark each seep in the field. The temperature and conductivity of each seep of interest will be measured, and locations with less than 30 mS/cm conductivity will be targeted. Qualitative flow rate estimates will be made at each seep using the following categories: high flow (e.g., active flow), medium flow (e.g., smaller stream), or low flow (e.g., trickle). The lowest low tides will be targeted for the reconnaissance survey in order to increase the area of exposed bank and visible beach. The results of the reconnaissance survey will be relayed to EPA via email, and a discussion will be held to agree upon sampling locations. In addition, EPA oversight staff may be present during the reconnaissance to aid in decision making. The sampling will need to occur relatively soon after reconnaissance to take advantage of daylight lowest tides to increase available sampling time. All results will be summarized in the data report.

The sampling methods, the analyte list, and the corresponding analytical methods will be provided in the seep QAPP. The analyte list will include the COCs listed in Tables 19 and 20 of the ROD (EPA 2014).

3.3 Task 4: Sampling and Analysis

Once the QAPPs (described in Section 3.2) are approved by EPA, field sampling will be conducted and the collected samples will be analyzed according to the QAPP-specific protocols.

Targeted sequencing[63] of the field events is presented in Figure 3-4 and summarized as follows.

- Fish and crab sampling will be conducted in August/September 2017 to match the sampling period in the RI (Windward 2010a).
- Multiple surface water sampling events will be conducted targeting a range of flow conditions, starting in the dry season of 2017 and concluding in 2018.
- Surface sediment sampling (0–10 cm) and source-related sampling near outfalls[64] will be conducted in February or March 2018.

[63] The actual dates are subject to change depending on approval dates of the QAPPs.

- Clam tissue, intertidal sediment (0–45 cm), banks, and seeps will be sampled in May and June 2018 during low tides to allow the greatest extent of the intertidal area to be sampled.

[64] Collection of some source-related sediment samples may be delayed to May/June 2018 if it is determined that low-tide conditions would facilitate the collection of specific samples.

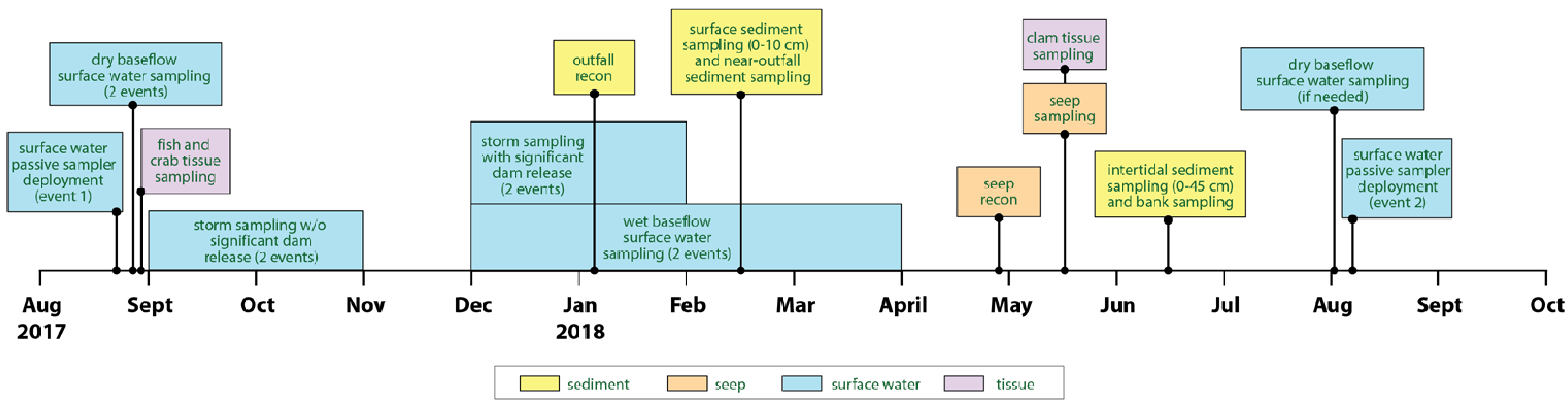

Figure 3-4. Targeted sampling timeline

3.4 TASK 5: SAMPLING DATA REPORTS

Under Task 5, six data reports will be prepared after the completion of each of the following sampling events. Specifically, the following data reports will be prepared:

- Sediment (LDW-wide 0–10-cm samples and near-outfall source identification samples)
- Intertidal sediment (0–45 cm) and banks
- Fish and crab tissue
- Clam tissue
- Seeps
- Surface water (while there will just be one data report [with all water data], validated data will be submitted to EPA after each interim sampling event)

The data reports will contain validated data in tabulated format,[65] data validation reports, laboratory data reports, field forms, and photographs documenting the work conducted. Any deviations from the QAPPs will also be documented. Data will be submitted in electronic data deliverable format to EPA and uploaded to both EIM and SCRIBE. Some portions of data report (e.g., laboratory data reports) will only be submitted in electronic format to conserve natural resources.

Maps in the data report will only include sample locations (including trawl and crab pot locations); data will be mapped in the data evaluation report (Task 6, Section 3.5). All data interpretation, including the calculation of 95UCLs, will be conducted as part of the data evaluation report.

3.5 TASK 6: DATA EVALUATION REPORT

In Task 6, the results of the pre-design study sampling data will be evaluated as described below. One data evaluation report will cover the results of all pre-design investigations included in Task 4 of this work plan. Specifically, the data evaluation report will:

- Specify whether the data collected in Task 4 met DQOs outlined in the QAPPs.
- Provide tables, maps, results of statistical analyses (such as 95UCLs), supporting calculations, and narrative interpretation of baseline data relative to cleanup levels in ROD Tables 19 and 20, surface water ARARs, and TTLs presented the ROD Table 21 (EPA 2014).

[65] Data tables will include maximum, minimum, mean, and frequency of detection.

- Develop SWACs using baseline[66] data for all contaminants with site-wide cleanup levels for surface sediment (0–10cm), and compare these values with RI/FS pre-EAA SWACs and bed composition model (BCM) post-EAA model prediction.
- Compare BCM input parameters from the FS (bed replacement and upstream and lateral chemistry values) against available results[67] for these inputs, and make recommendations for revised input parameters that may be used in future modeling to refine natural recovery predictions.
- Prepare GIS maps with the following layers to be posted on the LDWG website: RI/FS data, Task 4 data, and Task 2 sediment data.
- Provide an assessment of the porewater data collected, as outlined in the porewater addendum to this work plan (Appendix E).
- Identify data gaps and issues, and present recommendations to resolve any gaps or issues requiring additional field characterization or other work.
- Compile a list of any new datasets added to the LDW database since the Task 2 data compilation.

The report will be prepared following submittal of all draft data reports, with the exception of the surface water data report. The surface water data will be evaluated in an addendum to the data evaluation report.

In addition, if requested, LDWG will support EPA in making the GIS maps accessible via the Internet.

3.6 Task 7: Work Plan for Waterway User Survey and Assessment of In-water Structures

Under Task 7, a separate work plan was prepared for the waterway user survey and assessment of in-water structures. The Task 7 draft work plan was approved by EPA on April 19, 2017 (Integral and Windward 2017). That work plan provides details for Tasks 7 and 8, including the roles, responsibilities, and approach for conducting the survey and assessment, the data compilation and reporting procedures, and the schedule for completing the work.

In brief, the main objective of the survey and assessment is to gather information that will inform recovery category recommendations and technology assignments (EPA 2016). The survey and assessment will focus on the collection of data related to the physical conditions of the waterway—one of three lines of evidence (LOEs) considered in the determination of recovery categories in the ROD (EPA 2014). The remaining two LOEs (sediment transport and contaminant trend characteristics) will be reviewed, as

[66] Baseline data are defined as those collected to characterize baseline in Task 4 of this work plan.
[67] Available results include the data gathered as part of Tasks 2 and 4, which include updates from EIM.

needed, during design. Final technology assignments will also be determined during design, based on decision criteria identified in the ROD.

3.7 Task 8: Report for Waterway User Survey and Assessment of In-water Structures

Under Task 8, the survey and assessment described in the Task 7 work plan (Integral and Windward 2017) will be implemented, and a report that summarizes the activities and results will be prepared. The Task 7 work plan provides the details of the scope and approach. The report will support the development of recovery category recommendations, which are described as Task 9 (Section 3.8).

3.8 Task 9: Recovery Category Recommendations Report

The purpose of Task 9, the recovery category recommendations report, is to assess the recovery category designations presented in the ROD (EPA 2014) and provide recommended modifications, if necessary, based on the findings of the survey and assessment. In this task, the recovery categories map from the ROD will be updated with information collected during Task 8 related to waterway uses and associated in-water structures. The revised map will include annotations that summarize the basis for any proposed recovery category modifications.

The LDW FS (AECOM 2012) defined recovery categories to facilitate the assignment of RALs and remedial technologies to specific areas of the site. The recovery categories were developed based on the potential for contaminant concentrations in sediment to be reduced through natural recovery, or for subsurface contamination to be exposed at the surface due to physical processes (i.e., erosion and scour). Based on the recovery category designations, capping and dredging were assigned to areas with less potential for natural recovery and a higher likelihood of disturbance. ENR and MNR were assigned to areas where recovery is predicted to occur and disturbance is less likely.

The recovery category designations and the criteria used to develop them are presented in Table 3-9 (adapted from ROD Table 23[68] (EPA 2014)). Recovery categories were assigned in the FS (AECOM 2012) by mapping physical criteria and chemistry trend information. Physical criteria included bathymetric evidence of vessel-induced scour, the presence of berthing areas, and modeled predictions of high-flow-induced scour and long-term sedimentation. Temporal contaminant trends were evaluated by reviewing COC concentrations at reoccupied surface sediment sampling locations and vertical profiles of COC concentrations in cores.

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[68] ROD Table 23 is titled *Criteria for assigning recovery categories.*

Table 3-9. Recovery category designation criteria

Criteria		Category 1 – Recovery Presumed to be Limited	Category 2 – Recovery Less Certain	Category 3 – Predicted to Recover
Physical criteria				
Physical conditions	vessel scour	observed vessel scour	no observed vessel scour	
	berthing areas	berthing areas with vessel scour	berthing area without vessel scour	not in a berthing area
STM	STM-predicted 100-year high-flow scour	> 10 cm	< 10 cm	
	STM-derived net sedimentation	net scour	net sedimentation	
Rules for applying criteria		If an area is in Category 1 for any one criterion, that area is designated Category 1.	If conditions in an area meet a mixture of Category 2 and 3 criteria, that area is designated Category 2.	An area is designated Category 3 only if it meets all Category 3 criteria.
Empirical contaminant trend criteria – used on a case-by-case basis to adjust recovery categories that would have been assigned based on physical criteria				
Resampled surface sediment locations		If increasing PCB or increasing concentrations of other detected COCs exceed the SCO (> 50% increase), the area is designated Category 1.	If equilibrium and mixed (increases and decreases) results are detected (for COCs that exceed the SCO), the area is designated Category 2.	If decreasing concentrations (> 50% decrease) or mixed results (decreases and equilibrium) are detected, the area is designated Category 3.
Sediment cores (top 2 sample intervals in upper 60 cm)				

Source: Adapted from ROD Table 23 (EPA 2014).

COC – contaminant of concern
PCB – polychlorinated biphenyl
ROD – Record of Decision
SCO – sediment cleanup objective
STM – sediment transport model

The data collected in Task 8 will inform the "physical conditions" in Table 3-9 relating to vessel scour and berthing areas. While direct observation or modeling of vessel scour will not be performed as part of this task, the data gathered under Task 8 will facilitate the identification of areas potentially subject to scour or other disturbances based on current vessel movement patterns and berthing operations. These potential scour areas will then be overlain on the recovery category map (Figure 12 of the ROD (EPA 2014)[69]) to assess where adjustment may be needed, and to focus on any supporting location-specific investigations or analyses that may be needed during design.

The recommendations developed in the recovery category recommendations report will be based on the physical conditions findings of the survey and assessment. This report will be written before the results of the baseline and source-related sampling are available. Therefore, additional data (beyond what was used for the FS (AECOM 2012))

[69] ROD Figure 12 is titled *Recovery Category Areas*.

to inform the "empirical contaminant trend" criteria will be limited to those compiled as part of the Task 2 data compilation. The remedial design data will be used to delineate the boundaries of remedial technologies and to finalize recovery category areas.

3.9 Task 10: Design Strategy Recommendations Report

The purpose of the design strategy recommendation report is to develop a conceptual approach and schedule for acquiring the data needed to complete the design for the LDW selected remedy.

The pre-design studies presented in this work plan represent data gathering efforts to establish baseline site conditions, inform the design phase, and assist in gathering source control sufficiency data for Ecology.

As part of design, location-specific environmental and physical data will be collected. Environmental data (e.g., surface and subsurface sediment chemistry) will be collected to refine remedial boundaries and technology assignments; these data will also be used to support other aspects of the design (e.g., cap modeling). Physical data (e.g., sediment geotechnical properties and bathymetry) will be collected to support design elements such as dredge prism and cap designs. In addition, certain planning information will be collected to support the logistical aspects of remedy implementation, including details vital to accommodating waterway users who may be affected by construction activities.

A detailed list of the various data needs for the design phase is presented in Appendix D. This list includes various data objectives, data types, collection methods, and timing considerations.

In preparing this list, thought was given to whether any time-critical data needs exist (beyond those addressed by the efforts that are currently underway) that should be addressed or initiated before the design phase in order for the LDW remedy process to proceed in a timely fashion. Based on the evaluation done for this work plan and the state of practice for phasing large remediation projects, LDWG believes that there are no additional collection efforts that would normally precede the collection of location-specific environmental and physical data. In other words, the collection of such data is the next critical path step in the design process. The design strategy report and discussions preceding it will present additional details about how design data collection efforts will be implemented efficiently to allow for the timely implementation of the remedy. There may be segregable design tasks that can be completed ahead of the critical path tasks, if appropriate.

The design strategy report will describe the purpose and type of data needed to complete the various aspects of the design. The report will also provide a recommended strategy for timing and phasing of the design phase investigation activities, and will describe in greater detail the types of information typically generated by the construction contractor (and detailed in the remedial action work plan), such as transloading facility locations and operations, equipment types, haul routes, cap material sources, vessel management plans, tribal fishing coordination, detailed schedules, and hours of operation.

The design strategy report will also include a work breakdown structure, which will identify data collection activities required for each element of the design. For instance, the steps required to complete cap designs will be listed in order to identify all of the associated data needs. The other technology-specific and logistical elements of the engineering design will be similarly addressed. A conceptual schedule will be developed to illustrate the timing and sequencing of the corresponding data collection activities.

4 Schedule and Deliverables

Table 4-1 summarizes deliverables and their schedule based on requirements outlined in the third AOC amendment (EPA 2016). Numerous deliverables are being produced as part of the pre-design studies, including various QAPPs, data reports, and evaluation and strategy reports. The project schedule presented in Table 4-1 lists the deliverables that are required to complete the 10 tasks addressed in this work plan. Approval of this work plan is a key element in the linked schedule.

Numerous draft deliverables have already been submitted to EPA, as well as three final deliverables (Table 4-1).

Because many of the dates in the linked schedule are contingent, should a given date not be met, the delivery dates for linked deliverables will be shifted accordingly. In addition, dates beyond the submittal of draft documents are approximate and are dependent on the time required for receipt of EPA comments and resolution of any issues identified in the draft documents. Following the initial draft, EPA comments will be addressed in a revised report due 30 working days from LDWG receipt of EPA comments, unless otherwise approved or directed by EPA.

Table 4-1. Task deliverable schedule

Task No.	Description	Deliverable	Submittal Date to EPA
1	Work plan	annotated outline	Annotated outline is due 210 days from effective date of the third AOC amendment (submitted November 22, 2016).
		draft work plan	Draft work plan is due 60 days from EPA comments on the outline (submitted February 21, 2017).
		draft porewater addendum	Draft addendum due 45 days after submittal of draft work plan (submitted April 17, 2017).
2	Existing data compilation	draft technical memorandum	Draft memorandum is due 255 days from effective date of the AOC third amendment (draft submitted January 6, 2017; draft final submitted March 13, 2017).
		draft groundwater data compilation	Draft groundwater data compilation due 45 days following receipt of EPA comments on the Task 2 data compilation memorandum (submitted March 22, 2017).
3	QAPPs[a]	draft fish and crab tissue QAPP	Draft QAPP is due 45 days after EPA approval of the Task 1 work plan.[a]
		draft sediment QAPP	Draft QAPP is due 45 days after EPA approval of the Task 1 work plan.
		draft clam tissue QAPP	Draft QAPP is due 89 days after EPA approval of the Task 1 work plan.
		draft surface water QAPP	Draft QAPP is due 45 days after EPA approval of the Task 1 work plan.[b]
		draft seep QAPP	Draft QAPP due 68 calendar days after EPA approval of the Task 1 work plan.
4	Sampling and analysis	not applicable	Initiate and complete sampling per approved QAPP schedule.
5	Sampling data reports	draft fish and crab tissue data report	Draft data report is due 21 days after receipt of validated data.
		draft sediment data report	Draft data report is due 21 days after receipt of validated data.
		draft clam tissue data report	Draft data report is due 21 days after receipt of validated data.
		draft surface water data report	Draft data report is due 21 days after receipt of validated data (each round).
		draft seep data report	Draft data report is due 21 days after receipt of validated data.
6	Data evaluation report	draft report	Draft data evaluation report is due 60 days after submittal of draft sampling data report.[c]
7	Work plan for waterway user survey and assessment of in-water structures	draft work plan	Draft work plan is due 225 days after effective date of the AOC third amendment.[d]
8	Report for waterway user survey and assessment of in-water structures	draft report	Initiate survey within 30 days of EPA approval of Task 7 work plan. Draft report is due 45 days after completion of Task 8 survey.

Table 4-1. Task deliverable schedule

Task No.	Description	Deliverable	Submittal Date to EPA
9	Recovery category recommendations report	draft report	Draft report is due 45 days after approval of the Task 8 report.
10	Design strategy recommendation report	draft report	Draft report is due 60 days after submittal of the draft Task 8 report.

[a] The draft fish/crab QAPP was submitted on May 12, 2017; the QAPP was approved by EPA on July 13, 2017.

[b] The draft surface water QAPP was submitted on June 19, 2017; the QAPP was approved by EPA on August 2, 2017.

[c] There will be a series of data reports; the data evaluation report will be submitted following submittal of all of the draft data reports, except for the surface water data report (these results will be evaluated in an addendum).

[d] The draft Task 7 work plan was submitted on December 7, 2016; the work plan was approved by EPA on April 19, 2017.

AOC – Administrative Order on Consent

EPA – US Environmental Protection Agency

LDWG – Lower Duwamish Waterway Group

QAPP – quality assurance project plan

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